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THE METALLOGRAPHY OF ALUMINUM.*

BY

ROBERT J. ANDERSON, B.S., Met.E.,
Cleveland, Ohio. Member of the Institute.

I. INTRODUCTION.

ALUMINUM is the lightest of the commercial metals which are used in large quantities, having a density of 2.702 ± ; once obtained in ingot form, it can be worked and fabricated with moderate ease; metallographically, it is one of the most interesting of any substantially pure metal known; from the physico-metallurgical standpoint, very little is known about it. Aluminum has usually been assigned by metallographic writers to the isometric system, but late research has shown it to be tetragonal (1, 2)[1]. The remarkable method of crystal analysis developed by Laue and the Braggs and modified by Hull has shown that the unit of structure of aluminum is a centred rectangular prism with square base 2.85 angstroms by 2.85 angstroms and height 4.85, with an atom at each corner and one in the centre of the prism; the number of atoms per unit parallelopiped is two. The methods of X-ray analysis of Bragg (3) are applicable to individual crystals of appreciable size which are reasonably free from twinning, and developed sufficiently to permit the determination of the direction of their axes. Hull's method is a modification of Bragg's, and can be applied to all crystalline substances. Briefly, it consists in

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* Communicated by the Author.

[1] References are to Bibliography.

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sending a narrow beam of monochromatic X-rays through a disordered mass of small crystals of the substance whose crystal habit is to be determined and then photographing the diffraction pattern produced. Aluminum has not, in general, been regarded as allotropic, but the available evidence would arouse suspicion that it may be; such suspicion is based on the fact of greatly altered physical properties in the aluminum alloy duralumin on heat treatment, while Lashchenko (4) has found a thermal change at 580–590°C. Lashchenko noticed a break in the cooling curve of aluminum between 580 and 590°C., indicating transformation into an allotropic variety, the change being accompanied by a thermal effect of 3.5 calories per gram of aluminum. Cohen (5) found that the specific-heat-temperature curve was not continuous. Whether aluminum is allotropic or not still remains to be shown with an abundance of unmistakable data.

As I have said many times before, information on the metallography of aluminum is almost negligible—in fact, the metallographic study of this metal may be said to have just begun. A reasonable amount of metallographic investigational work has been performed with great diligence by the Alloys Research Committee of the Institution of Mechanical Engineers (56, 57, 58) on the aluminum-rich alloys of commercial importance; *viz.*, aluminum-copper, aluminum-copper-manganese, and aluminum-zinc alloys. A series of recent papers (6) has given valuable data in compact form on the physical properties of aluminum, to which reference may be made for particular information.

Off-hand, it may appear desirable, in view of what has just been said, to confine the present paper to a description of the microstructure of various forms of aluminum, but a moment's reflection will render it evident that it will be better to briefly discuss also our fundamental metallographic notions, so that the metallography of aluminum may be considered in terms of modern conceptions and interpreted in relation to other metals. Accordingly, the present paper will consist of a brief discussion of the amorphous theory and plastic deformation, with some remarks on grain growth phenomena; while the microstructure of various forms of aluminum, cast, worked, and annealed, will be treated in greater detail. The annealing and recrystallization of aluminum which has had plastic deformation will be described at some length, and there will be included a section on exaggerated grain growth in deformed aluminum, together with a short note on the polishing and etching of aluminum microsections preparatory to microscopic examination.

II. THE AMORPHOUS THEORY AND PLASTIC DEFORMATION.

As is well known, substantially pure metals in the solid state consist of a greater or less number of allotriomorphic grains or crystals. Crystallographically, such crystals are referred to as allotriomorphic (not idiomorphic), since their shape is determined by neighboring crystals, but metallographers prefer, usually, to call them simply grains. Liquid pure metals are held to be amorphous, since their molecules are not arranged in any systematic way. When the temperature of a liquid metal is lowered to the freezing point, crystallization commences from various nucleii. Without taking time now to examine the mechanism (7) of freezing and crystallization, the ultimate structure of a frozen metal consists of an aggregate of grains, each one of different orientation than its neighbor; the regular allotriomorphic structure normally results unless there are specific conditions under which the rate of cooling or the presence of impurities is such as to give rise to a cellular or dendritic structure. Metals and alloys are found to be widely different in physical properties (in the same metal or alloy), depending upon whether they are cast, worked, or annealed, and among all the theories submitted to account for the existing differences, that laid down by Beilby (10) and elaborated upon by Bengough (11), Rosenhain and Ewen (12), and Rosenhain (13) has the largest number of adherents among metallographers.

Beilby's Amorphous Theory.—Beilby demonstrated some time ago that during the ordinary operations of polishing a sample of metal an amorphous surface film is produced. In essence, Beilby's theory submits, and this is now generally accepted, that when a metal undergoes plastic deformation the various sections of the individual grains slip along their gliding or cleavage planes and by so slipping generate amorphous metal at these planes. Further, it is believed, that amorphous metal is also generated at the grain boundaries, during plastic deformation. This generation of amorphous metal makes a worked metal stronger and harder than an annealed metal because the amorphous phase is stronger and harder than the crystalline phase; the amorphous phase is assumed to be entirely non-plastic. The amorphous phase is that of minimum thermal stability and maximum mechanical stability, while the reverse is true of the crystalline phase; thus, the effects of heat are to change amorphous metal into crystalline. In accordance with this theory, then, it is found that when the elastic limit of a metal is exceeded and plastic deformation begins to act, slipping takes place along the cleavage or gliding planes of the individual crystals, resulting in a relatively high temperature localized at the slipping planes. At the temperature so produced the slipping action generates amorphous metal according to

$$\text{Crystalline} \leftrightarrows \text{Amorphous}$$

and the amorphous metal so generated acts in the manner of a lubricant to promote slip. Whether the temperature is high enough to actually melt small particles torn away by the slip or not, the metal at the slipping planes is for a moment very mobile; the mobile metal does not so remain long, but passes into the hard, amorphous state, which is stronger and harder than the crystalline. Those portions where amorphous metal has been generated are stronger than other portions where no slip has occurred, and with further deformation the metal is amorphized more—the deformed piece becoming harder and stronger with the increase in amount of the amorphous phase.

Amorphization in a metal undergoing plastic deformation eventually comes to an end; it is not held possible to convert all of the crystalline phase into the amorphous, since comparative brittleness finally sets in, and the metal breaks. Most of the phenomena of the plastic deformation of metals can be readily explained by the above theory, which preceded Rosenhain's amorphous cement theory. Other theories have been advanced to account for the phenomena under discussion, some of which can be interpreted in terms of the amorphous theory, while others appear to be non-applicable.

Rosenhain's Amorphous Cement Theory.—Rosenhain and Ewen (12) and Bengough (11) have strongly advocated the existence of an amorphous cement at the boundaries of a frozen metal. According to this theory, the crystals of a pure metal are surrounded and cemented together with a very thin layer of the same metal in the amorphous state. This amorphous cement is presumed to arise from the assumption of an indivisible crystal unit, and that during the formation of a crystal, crystalline material is added unit by unit, each unit consisting of several molecules. At the moment of final freezing the space between grains is too small to allow crystallization of the liquid metal there, since the space is not large enough to contain a crystal unit. Accordingly, the metal at the grain boundaries will remain in the amorphous state because the molecules will not have arranged themselves with the change of position accompanying crystallization for the particular metal. The existence of an amorphous cement explains many observed facts with reference to the physical properties of coarse- and fine-grained metals; however, if we hold with Bragg that crystal units are of less than molecular dimensions, then some difficulties arise with the amorphous cement theory. Lately, Rosenhain appears to have accepted the Bragg belief as to the size of crystal units. The evidence, however, submitted in favor of the existence of an amorphous cement includes: (1) the greater loss by volatilization on heating *in vacuo* from fine-grained than coarse-grained zinc, copper, and silver; (2) the intergranular fractures yielded by gold, tin, lead and bismuth at temperatures just below their melting points; and (3) the more rapid attack of etching reagents on the grain boundaries.

Quincke's Foam-Cell Hypothesis.—Prof. Georg Quincke (14) has advanced an interesting theory to explain the crystallization of metals. According to Quincke, the first step in the process of crystallization of a liquid is the separation of the liquid into two immiscible liquid phases, of which one is in subordinate amount to the other. This liquid arranges itself in a manner, often seen in immiscible oils and aqueous solutions, to form the walls of foam cells filled with the liquid which is present in greater amount. The arrangement of the crystalline particles when solidification takes place is determined then by the presence, size, and form of the foam cells. Referring in particular to metals, it is alleged that the crystal grains are the foam cells, and the boundaries of the grains are the foam walls. Hence, coalescence on annealing is held to be a manifestation of a foam to become coarser, this being interpreted to fit the case where small grains coalesce to form large ones. Other evidence in favor of foam cells is pointed out; *viz.*, the more rapid corrosion of the grain boundaries on etching is supposed to result from the difference in composition of the foam walls and the foam cells; and in the same way the more rapid volatilization of the grain boundaries on heating *in vacuo* is explained. However applicable Quincke's theory may be to the study of emulsions and liquid crystals, it looks as though the foam theory postulates entirely too much when the attempt is made to apply it to metals.

Rosenhain's critical discussion of Tammann's objections to the amorphous cement theory has been sensible and instructive, and it is noticeably free from the labored attempts to adapt the theory to a certain scheme, as is the case with Quincke's theories.

Cold-Worked vs. Annealed Metal.—Microscopically, it is usually easy to distinguish worked from annealed metal, and there are, further, many differences in physical properties between any metal in the cold-worked and annealed conditions. The cold-worked metal has greater elastic limit and ultimate strength, and less elongation; the reduction in area of a cold-worked metal is usually less. Cold-working, resulting in permanent deformation, causes increased hardness, and in many cases increased density, though further cold work may again decrease the latter. A cold-worked metal, *i.e.,* one which has been permanently deformed below the temperature at which complete recrystallization takes place, consists of films of the amorphous phase in contact with the crystalline, whereas an annealed metal is practically physically homogeneous. In the foregoing it has been said that it is not possible to completely amorphize a ductile metal by work; for instance, it has been shown by Beilby that when a ductile metal is severely worked, as in wire drawing, where the metal is drawn repeatedly through smaller and smaller dies, that the distorted grains, even though enormously elongated, retain a crystalline core encased in an amorphous shell. In the cold rolling of ductile aluminum we have exfoliation of fine scales and thin films, indicating localized peeling away by fracture of small portions of the partly amorphized surface.

Amorphous metal is more electro-positive than crystalline metal (15), as can be shown by measuring the difference in potential between annealed and cold-worked samples of the same metal. Cold-worked metals are then both more electro-positive and more heterogeneous physically than otherwise identical annealed metals. The electric conductivity of a cold-worked metal is less than that of an annealed one, while of the heat of solution the reverse is true.

Plastic Deformation.—Deformation, below the temperature of recrystallization, of a ductile metal, by such mechanical processes as rolling, forging, drawing, and the like, greatly alters its physical properties. We have seen that metals are granular, and we have now to touch briefly on the effect of deformation on the crystalline structure of metals. Any stress within the elastic limit of a metal results in an elastic deformation, from which the metal recovers completely upon release of the stress. Stress exceeding the elastic limit results in plastic deformation, recognized as a permanent set, and at the same time increases the elastic deformation. Plasticity in a ductile metal is marked by the ability which it has for passing through a relatively weak phase and into a strong phase; the strong phase is held to be amorphous and does not return to the weak phase unless recrystallization is effected. The changes in physical properties by plastic deformation are those which must necessarily follow from amorphization, as has already been shown, and Beilby's theory very satisfactorily explains the mechanism of such deformation.

III. SOME OBSERVATION ON GRAIN GROWTH PHENOMENA.

The mechanism of grain growth in metals has lately been subjected to conditions of careful experiment, and in the past few years considerable data have been assembled to explain this phenomenon. I may mention in passing that the determination of grain size as a routine procedure in works laboratories has not been deemed so important as it was once thought it would be. A few remarks on grain growth in metals may be properly included in the present paper since it will be well to have the main points in mind when discussing exaggerated grain growth in aluminum, to be taken up in a later section. Rapid cooling of metals is conducive to fine-grain size, whereas slow cooling results in relatively coarse grains; largest grains, in a cast metal, are the result of holding the metal for a long time at or near the freezing point. Grain size in worked and then annealed metals depends upon the amount of prior plastic deformation, and the annealing conditions (time of exposure and temperature). The physical properties of metals are connected intimately with the grain size, and its influence can be readily understood on the basis of the amorphous cement theory (11, 12, 13).

The smaller the grain size of any given metal, the greater the amount of amorphous cement between the grains; therefore, the fine-grained metal, having more of the strong cement than a similar coarse-grained metal, is stronger. The fine-grained metal has greater ultimate strength and elastic limit than a coarse-grained metal, and also higher elongation. Further, the fine-grained metal stands up better under shock and fatigue. Smoothness of surface is an important requisite in sheet metal for industrial drawing operations, and a definite minimum grain size will insure surface smoothness (28).

Metals and metallic alloys may be subjected to plastic deformation, and, under definite conditions, recrystallization and grain growth ensue on annealing. The temperature of most rapid growth is a function of the amount of deformation—which implies that for a certain definite deformation there is a critical temperature at which grain growth proceeds with the greatest rapidity. This temperature of fast growth is definite, within certain limits, and any greater or less temperature for a particular deformation will result in less rapid growth. This leads to a consideration of the important germinative temperature phenomenon which was advanced in its present form by Jeffries (29) and elaborated upon by Howe (30).

Germinative Temperature Phenomena.—Broadly stated, a given set of grains which do not grow in the cold will commence to grow on heating to a certain temperature, and will continue to grow at all higher temperatures. The so-called germinative temperature is defined as that temperature at which growth begins. There accordingly exist two temperature ranges with reference to the germinative temperature; *viz.,* (1) an inert range below it, and (2) a growth range above it. In the event that only part of a differentially strained piece of metal is at the germinative temperature, this becomes the fast-growth temperature for that particular part, and the germinant grains grow by boundary migration, feeding on the adjacent inert grains. In such instance, we have the greatly exaggerated growth of Sauveur (32), Chappell (33), Jeffries, *et al.* Similar exaggerated growth has been observed by the present writer (34) in the case of aluminum, which is more fully described in this paper. The late results of White and Wood (38) indicate that germination is not alone dependent on temperature, but that it may occur after a relatively long exposure at a temperature which would not bring it about after a short exposure.

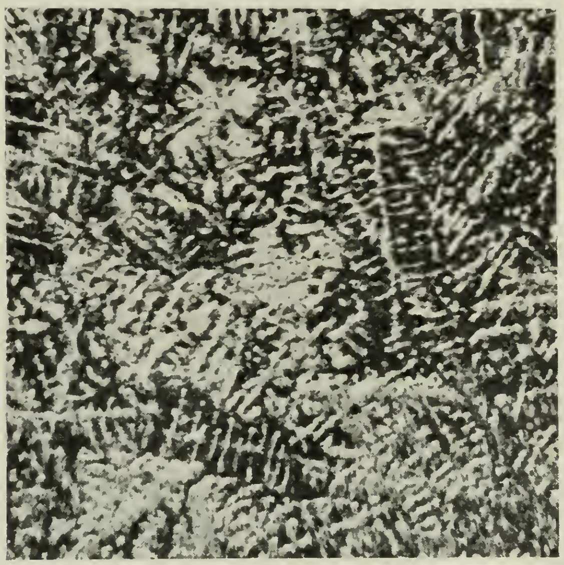
Grain growth is influenced, among other things, by the fineness of grain, by the grain-size contrast, and by the amount of prior plastic deformation; these factors also affect the position of the germinative temperature. Temperature is a leading factor, and grain growth proceeds more readily at higher temperatures. On the other hand, growth is opposed by obstructing material such as cementite, slag, and other sonims in iron, and by thorium oxide in tungsten, as well as by the decrease in the grain-size contrast. For the reasons just given, the germinative temperature is raised. There is, of course, no growth on annealing unless there has been prior deformation. It has been found by Jeffries that although a long sojourn at a low temperature might result in exaggerated growth, a rapid heating to a high temperature might prevent it.

IV. THE INTERNAL STRUCTURE OF CAST ALUMINUM.

The crystalline character of metals was noted in the seventeenth century by Hooke (9) in connection with the microscopic study of fractured surfaces, and subsequent observation has shown that all metals are crystalline. When cast from the liquid state and cooled moderately slowly, substantially pure aluminum consists, like other metals, of an aggregate of allotriomorphic grains. No reports of idiomorphic crystals of aluminum have come to hand. Aluminum, however, readily forms dendritic crystals on solidification, and some instances have been observed of very striking dendritic structure. The best commercial aluminum is far from pure, ordinarily, when compared to the relatively high state of purity in which commercial copper, zinc, and tin are obtainable. This lack of purity does not, however, prove a handicap, except in special cases, to the utilization of the metal. An aluminum containing 0.15 per cent. Cu, 0.30 per cent. Fe, 0.30 per cent. Si, and 99.15 per cent Al (by difference) represents a fairly good commercial product at this writing. Metal containing up to 99.60 per cent. Al has been produced. The influence of the impurities iron and silicon is now believed to be more profound than was hitherto generally held, and there seems to be a very important relationship existing between iron and silicon, and between these elements and the aluminum itself, which, not only affects the properties of the metal but even of its alloys. Just what these relationships are is not known with certainty.

Condition of the Impurities.—In an aluminum of the analysis given above, if slowly cooled, the entire amount of copper is in solid solution; aluminum dissolves up to about 4.5 per cent. Cu in the solid state at 15°C. The iron forms an aluminum-iron compound, $FeAl_3$, which is but slightly, if at all, soluble in the solid state; while the silicon is present, probably entirely, as elemental silicon. Silicon can exist in aluminum in two forms; (1) as crystals of free silicon, and (2) in solid solution. In cold-rolled sheet aluminum, silicon is present to a considerable extent as free silicon, but on annealing the silicon appears to go into solid solution to a degree.

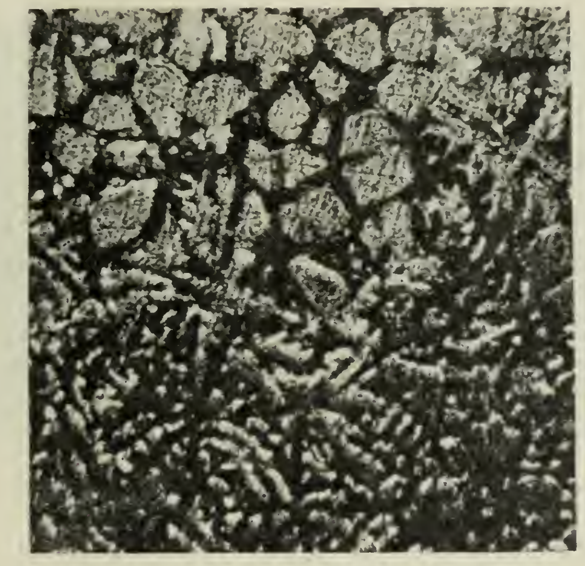
FIG. 1.



Chill-cast pig aluminum; dendritic structure; × 40.

Microstructure.—Turning now to an examination of the internal structure of substantially pure cast aluminum, reference may be made to the micrographs in Figs. 1 to 6 inclusive. Fig. 1 is a micrograph of chill-cast pig aluminum, the photograph having been taken at a point near the edge of the ingot; the structure is plainly dendritic (55). Fig. 2 is a micrograph of the same metal, but the photograph was taken at a point a little farther in towards the centre of the ingot where the structure is allotriomorphic; in this micrograph is shown the juncture of the dendrites and the allotriomorphic grains with one type of structure passing abruptly into the other. Fig. 3 shows the structure of deeply etched aluminum cast in a chill mould; the structure tends to be cellular. Fig. 4 illustrates at high magnification the microstructure of sand-cast aluminum, cast in the form of a tensile-test bar, while Figs. 5 and 6 are aluminum where the microsections were taken from gates in a sand casting. Unless otherwise indicated throughout this paper, the aluminum referred to as substantially pure metal means aluminum analyzing over 99 per cent.

FIG. 2.



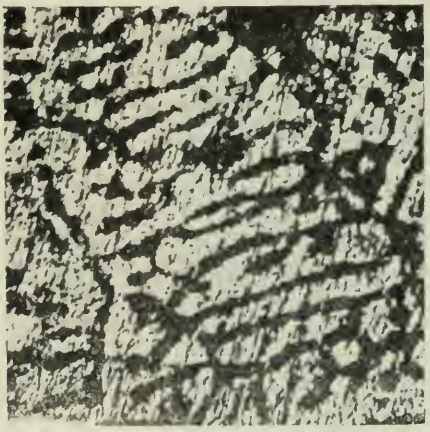
Juncture of dendrites and allotriomorphic grains in chill-cast pig aluminum; × 40.

Al, with the usual impurities, iron, silicon, and copper. The microstructure of aluminum in the cast condition is relatively simple; the structure consists of the grains of aluminum with the copper in solid solution and $FeAl_3$ segregated to the grain boundaries; the silicon when free appears to be both intra- and inter-granular. Not much pure aluminum as such goes into the production of castings, since the metal is ordinarily used in the form of an aluminum-rich alloy in the foundry. Most of the pure aluminum cast into ingots goes into the manufacture of sheet, wire, rods, bars, etc. The cast aluminum alloys are in general easier to etch for microscopic examination than is the metal itself.

V. ANNEALING AND RECRYSTALLIZATION OF COLD-WORKED ALUMINUM.

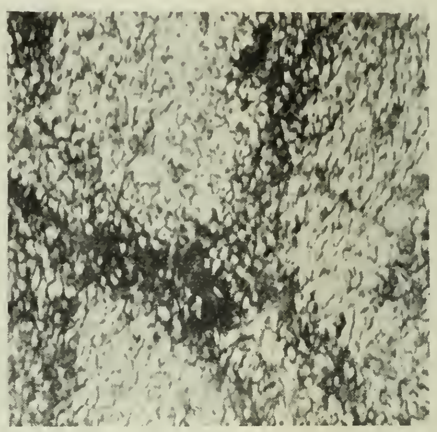
In brief, the effect of annealing cold-worked metals in general is to undo the internal changes set up by deformation—the result of annealing being, roughly, the restoration of the metal to its original crystalline condition, provided suitable precautions as to temperature and time of exposure for any given metal are observed. The first noticeable effect of heating cold-worked metal is the production of a small, but still readily detectable, increase in hardness, as has been shown by Mathewson, Thompson, *et al.,* and further heating causes softening; also, if the heating is sufficiently prolonged at a high enough temperature, the strained metal will become dead soft. Softening, as evidenced by the customary hardness tests, has been intimately associated with recrystallization, but this does not follow *per se,* as has been pointed out by Howe (31), for metals in general, and has been referred to by the writer for aluminum in particular (44). Going back to the slight increase of hardness observed after short exposure to heat in the case of cold-worked metals, recent observations have noted an increase of hardness in cold-rolled sheet aluminum after very short exposures.

FIG. 3.



Substantially pure aluminum; from centre of web of notch bar; × 78.

FIG. 4.

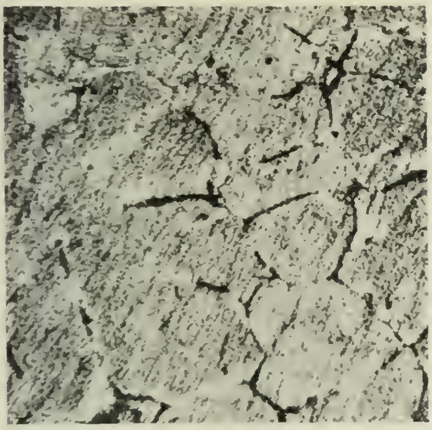


Sand-cast aluminum; from tensile bar; × 455.

The first systematic account of the various relations existing among the factors percentage of reduction, the alteration in physical properties and microstructure, and the time of exposure and temperature of anneal was set forth by the French engineer C. Grard (49), scarcely ten years ago, for rolled copper and brass.

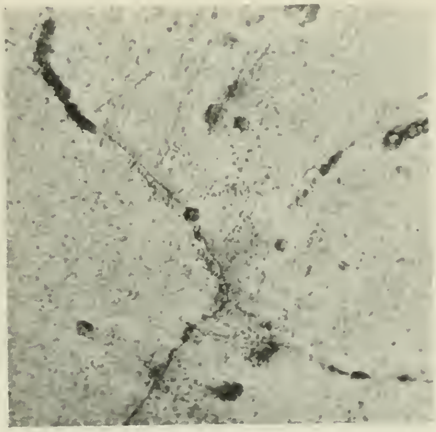
Further efforts in this direction have been extended by Bardwell for copper, Bengough and Hudson (50) for brass, Mathewson (48), and Mathewson and Phillips (42). The first account of the effects of heat at various temperatures on cold-rolled aluminum sheet was given only recently by Carpenter and Taverner (43), where unfortunately the percentage of reduction was not known, and still more unfortunately microscopy was not included. Elsewhere (44, 45, 46, 47), I have described the effects of heat at various temperatures on cold-rolled aluminum sheet of known percentages of reduction, as measured by the Erichsen ductility test and the Shore hardness; unfortunately also, microscopy was not completed. In the present section of this paper are included micrographs showing the alterations in structure accompanying exposure to heat at various temperatures of sheet aluminum of known percentages of reduction. Positive proof is now at hand which shows that severely worked aluminum (say percentage of reduction above 50.0) can be practically completely softened as indicated by the scleroscopic drop without complete recrystallization occurring.

FIG. 5.



Substantially pure aluminum; from gate in sand casting; etched with NaOH; × 75.

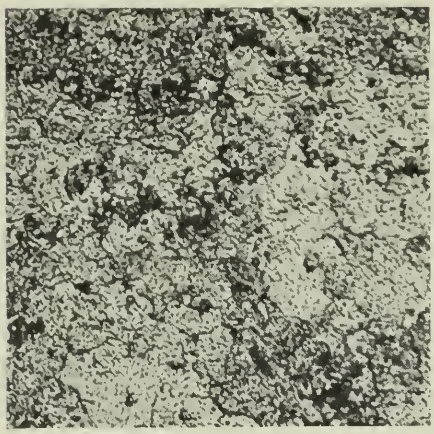
FIG. 6.



Substantially pure aluminum; from gate in sand casting; etched with NaOH; × 200.

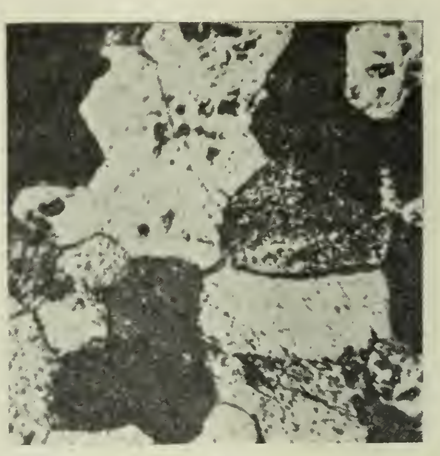
Rosenhain, in his book on physical metallurgy (25), has observed that aluminum is sluggish in recrystallizing, and this has also been confirmed by Brislee (51). Brislee, writing in a late paper (51) appears to tend toward the belief in an allotropic modification of aluminum, but no evidence is submitted. In the same paper he says: "The amount of cold work which can be done upon aluminum is limited by the formation of the amorphous state. Microscopic examination of polished and etched specimens taken at various stages during cold working shows that the crystalline structure disappears at a very early stage in the working, and unless the metal is annealed it will become fatigued, developing a species of 'Forcierkrankheit.' Aluminum which has been subjected to excessive cold work shows an entire absence of structure, and has the appearance of a metal which has flowed and passed into a vitreous state. The reverse change takes place with extreme slowness, and the ordinary annealing process does not change the structure from amorphous to crystalline. Aluminum annealed at a temperature of 500°C. for ten hours appears to be 'dead soft,' and has its maximum elongation; nevertheless it is still largely amorphous in structure when examined microscopically. Aluminum which has been annealed in this way hardens very rapidly when additional cold work is done upon the metal. The primitive crystals are transformed into the amorphous state much more readily than the larger crystals which are developed by annealing. The results of the specific heat determinations render the conclusion probable that under the influence of cold work aluminum is transformed into an amorphous variety."

FIG. 7.



Shore H. N.—5.0. Hot-rolled, 0.25-inch aluminum slab; × 100.

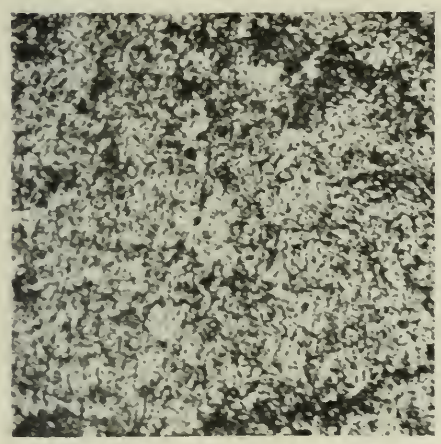
FIG. 8.



Shore H. N.—4.0. Hot-rolled, 0.25-inch aluminum slab; after 10-minute anneal at 595° C.; × 100.

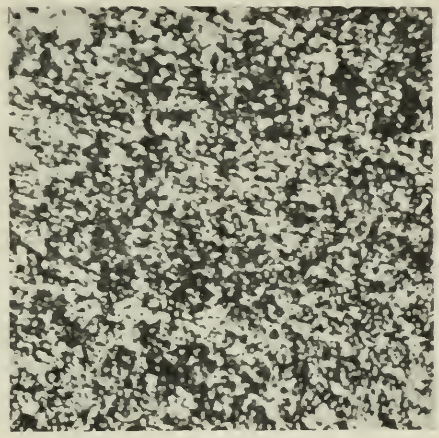
Seligman, in a discussion of the above, claims that he does not follow all of the arguments and does not confirm that as a general rule aluminum after ten hours' heating at 500° C. is largely amorphous in structure. The present writer does not entirely agree with Brislee's observations; however, the general trend of his remarks appears to accord with the known facts. Matweef (52) hardened aluminum by cold-hammering and afterwards annealed for five minutes at various temperatures; he concluded that aluminum did not begin to lose the work hardness so conferred until the definite temperature 350°C. had been reached. Rose (53) found that an impure aluminum containing 2.1 per cent. iron when in the cold-rolled condition had a scleroscopic drop of from 25 to 6, magnifier hammer (or 14 to 3.4, regular hammer) after a 30-minute exposure at 425°C. In a recent note on the annealing of aluminum (54), it was said that aluminum exhibits a certain sluggishness towards recrystallization, and it requires relatively higher temperatures, or longer times, or both, depending upon the amount of amorphous material present or the amount of deformation to bring about recrystallization, than would be expected. At the time the writer was not fully aware of the significance of the apparent wide range between the coalescence and softening zones of aluminum; it is true, however, that they are far apart.

FIG. 9.



Shore H. N.—15.0. Reduction—63.3 per cent. Cold-rolled, 12-gauge aluminum sheet; × 100.

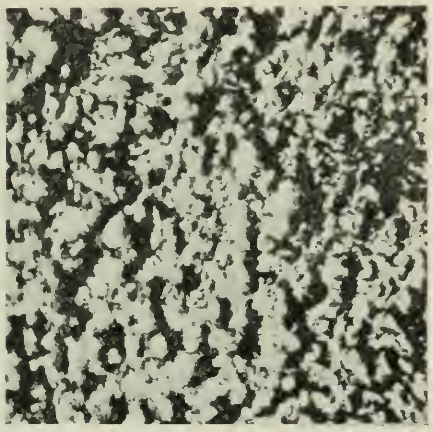
FIG. 10.



Shore H. N.—14.0. Reduction—71.6 per cent. Cold-rolled, 14-gauge aluminum sheet; × 129.

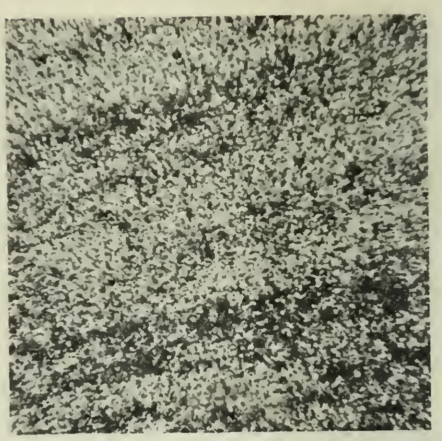
Microstructure of Hot-Worked Aluminum.—Hot work as ordinarily conducted leaves aluminum in a state of greater or less strain, since the finishing temperature is usually not high enough to effect self-annealing in the metal, *e.g.*, in a hot-rolled slab. The grains are left in a distorted condition, although the boundaries may be distinguished. This is illustrated by the micrograph in Fig. 7, which shows the internal structure of a hot-rolled 0.25-inch aluminum slab. The history of the metal just mentioned is as follows: the slab was produced by breaking down a 4-inch thick ingot, which had previously been heated for six hours at 455°C., to 0.25-inch thick with five or six passes in a hot mill; cross-rolling was done in the later stages. Referring to Fig. 7, it will be seen that grain boundaries can be readily distinguished, but that the individual grains are considerably distorted by the work. The effect of annealing at an appropriate temperature and for sufficient time is to cause recrystallization, as is illustrated in Fig. 8—a micrograph showing the internal structure after a ten-minute exposure at 595° C. The sample from which Fig. 8 was taken was etched rather deeply; such etching would be undesirable for grain-size determinations, since for this the boundaries should be developed sharply.

FIG. 11.



Shore H. N.—14.0. Reduction—71.6 per cent. Cold-rolled, 14-gauge aluminum sheet; × 370.

FIG. 12.

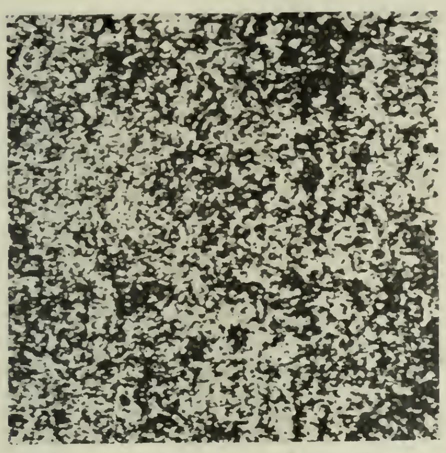


Shore H. N.—14.5. Reduction—82.6 per cent. Cold-rolled, 18-gauge aluminum sheet; × 75.

In the commercial production of sheet aluminum the metal is at first worked hot, and the final rolling to finished gauge is performed cold; the commercial reductions in the mill are often quite high, being, for some of the lighter gauges, up to 95 per cent. total reduction. This reduction is, of course, not all accomplished in one pass, but the metal is reduced gradually. Sheet aluminum so made is subjected to plastic deformation, and the amount of reduction is a very important factor in governing subsequent annealings.

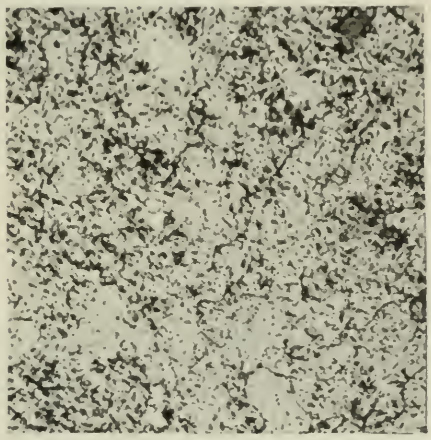
Microstructure of Cold-Rolled Aluminum.—When aluminum is rolled in the cold the deformation produces a certain amount of amorphous metal due to the slip of the individual grains as already outlined. Cold rolling of aluminum results in partial amorphization, where the individual grains are first elongated and then broken up, amorphous metal being formed; when examined under the highest available powers of the metallographic microscope, it is impossible to detect anything suggestive of crystallinity in hard-worked aluminum. By hard-worked aluminum, in general, is meant that which has had fairly large reduction. The internal structure of aluminum in this form is typically amorphous and flow lines in the direction of work are at times distinguishable. Micrographs in Figs. 9 to 13 inclusive show the internal structure of different samples of aluminum sheet, which had various reductions. By examining the micrographs closely, no evidence of crystalline structure can be found, and the metal is said to be amorphous. In the micrographs, indications of grain boundaries are still evident in Fig. 9, where the percentage of reduction was 63.3, but with increasing reduction these disappear. Indications of the direction of work are noticeable in Fig. 12.

FIG. 13.



Shore H. N.—14.0. Reduction—88.0 per cent. Cold-rolled, 22-gauge aluminum sheet; × 200.

FIG. 14.



Shore H. N.—5.0. Reduction—63.3 per cent. Twelve-gauge aluminum sheet; after 60-minute exposure at 350° C.; × 100.

The changes in microstructure which accompany exposure to heat in the case of cold-rolled aluminum are interesting, if difficult to interpret, and micrographs in Figs. 14 to 44 inclusive are included to show these changes. Annealings were made at various temperatures and for various times on samples of cold-rolled sheet aluminum of the following analysis:

Cu	0.25 per cent.
Fe	0.45 per cent.
Si	0.35 per cent.
Al	98.95 per cent. (by difference).

The softening effect of anneal was measured with the Shore scleroscope, and the microstructure was examined. In the micrographs, the percentage of reduction and the hardness after anneal are given for ready reference, and the summation of the results is tabulated in Table I.

TABLE I.

Effects of Heat at Various Temperatures on Cold-Rolled Aluminum Sheet of Different Percentages of Reduction.

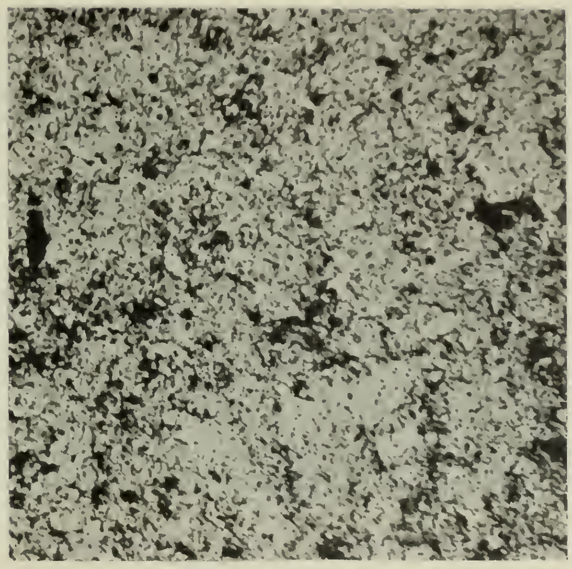
Refer to figs.	As rolled		Heat treatment		Shore H. N. after anneal	Sheet gauge	Remarks
	Percentage of reduction	Shore H. N.	Time in mins.	Temperature in degrees C.			
14	63.3	15.0	60	350	5.0	12	
15	63.3	15.0	60	400	4.6	12	
16	63.3	15.0	10	600	4.4	12	
17, 18	71.6	15.0	6	400	6.0	14	
19, 20	71.6†	11.5	10	400	6.0	14	Was ½ hard.
21	71.6	14.0	1440	370	4.0	14	Mill anneal.
22, 23	77.7	15.0	5	350	6.0	16	
24, 25, 26	77.7	15.0	240	525	5.0	16	
27, 28	80.0*	14.0	30	400	5.5	17	
29	80.0*	15.0	30	550–575	5.0	17	Furnace cooled.
30, 31	82.6	14.0	2	350	5.0	18	
32, 33	86.0	15.0	2	350	5.0	20	
34	86.0†	11.0	240	525	4.0	20	Was ½ hard.
35	86.0	15.5	30	550–575	5.0	20	Furnace cooled.
36, 37	88.0	15.0	1440	370	3.5	22	Mill anneal.
38	90.5	15.0	10	400	4.0	24	
39, 40	92.7	14.5	30	550–575	5.0	26	Furnace cooled.

* Approximately.

† Original reduction; this was within two gauge numbers of the finished gauge; the sheet was then annealed, and then reduced to gauge.

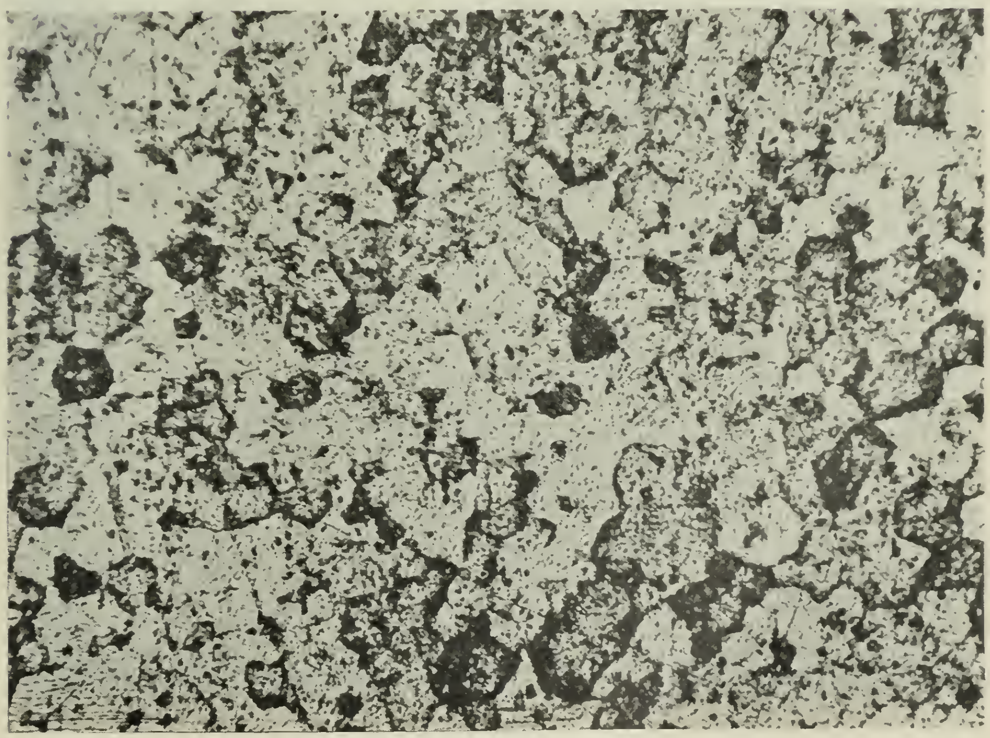
Alteration in Microstructure on Anneal.—A detailed discussion of the changes in internal structure accompanying annealing, with reference to Table I, will be given first, and some explanations will be offered later. Thus in Figs. 14, 15, and 16, which are

FIG. 15.



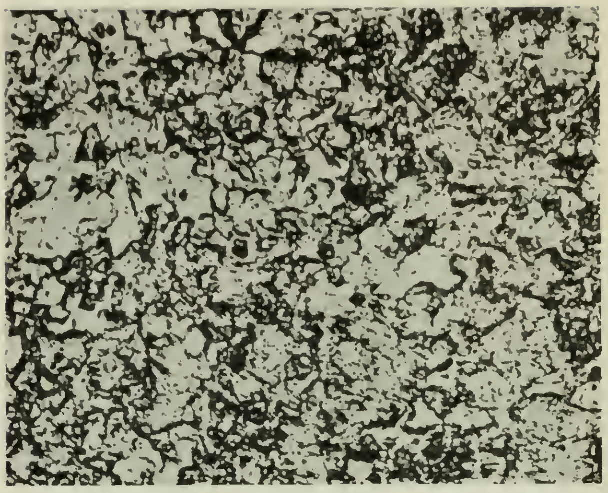
Shore H. N.—4.6. Reduction—63.3 per cent. Twelve-gauge sheet; after 60-minute exposure at 400° C.; × 100.

FIG. 16.



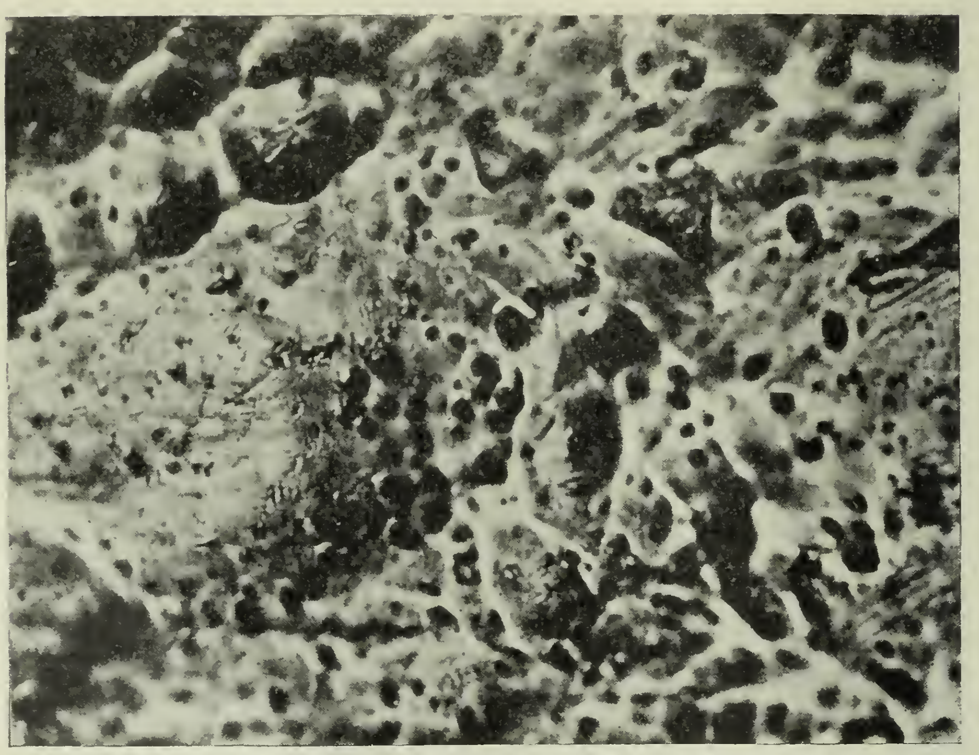
Shore H. N.—4.4. Reduction—63.3 per cent. Twelve-gauge sheet; after 10-minute exposure at 600° C.; × 100.

FIG. 17.



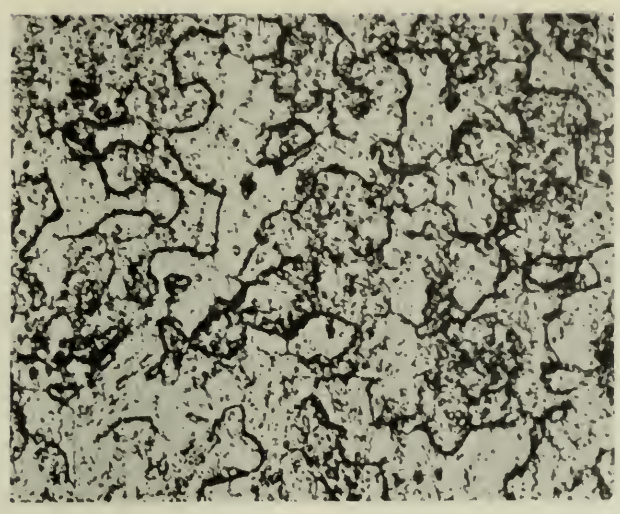
Shore H. N.—6.0. Reduction—71.6 per cent. Fourteen-gauge sheet; after six-minute exposure at 400° C.; × 100.

FIG. 18.



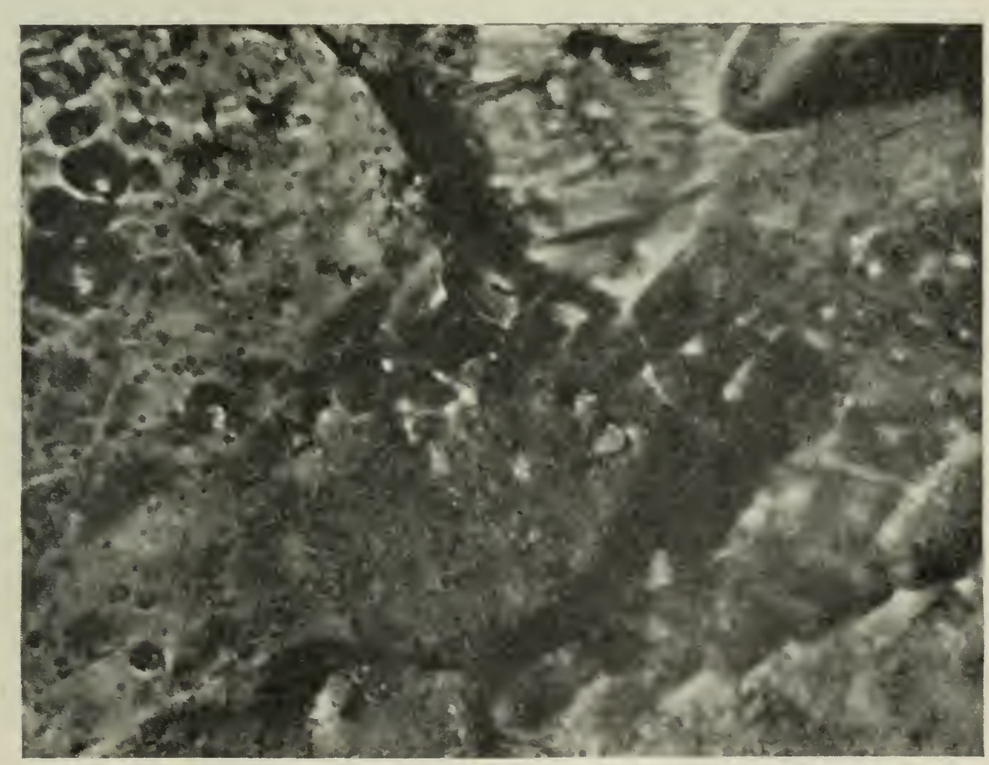
Shore H. N.—6.0. Reduction—71.6 per cent. Fourteen-gauge sheet; after six-minute exposure at 400° C.; × 1000.

FIG. 19.



Shore H. N.—6.0. Reduction—71.6 per cent. (?); was half hard. Fourteen-gauge sheet; after 10-minute exposure at 400° C.; × 100.

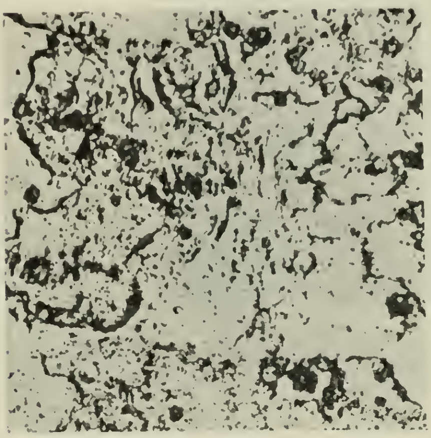
FIG. 20.



Shore H. N.—6.0. Reduction—71.6 per cent. (?); was half hard. Fourteen-gauge sheet; after 10-minute exposure at 400° C.; × 1000.

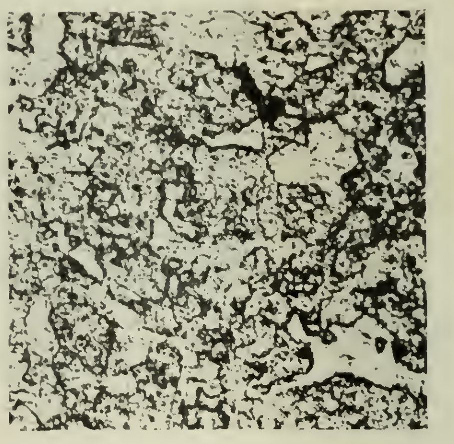
of 12-gauge cold-rolled sheet reduced 63.3 per cent., after various exposures at different temperatures, we find alteration in microstructure accompanying annealing, but there has apparently been no complete recrystallization. The scleroscopic drop was from 15 to 4-5, indicating practically complete softening. In Figs. 17 and 18 are shown the changes resulting from a six-minute exposure at 400°C. in the case of 14-gauge cold-rolled sheet, percentage of reduction 71.6; here again there has been considerable softening, as evidenced by the scleroscopic drop of from 15

FIG. 21.



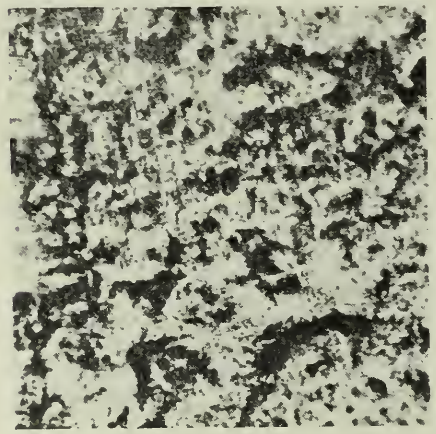
Shore H. N.—4.0. Reduction—71.6 per cent. Fourteen-gauge sheet; after 24-hour exposure at 370° C.; × 100.

FIG. 22.



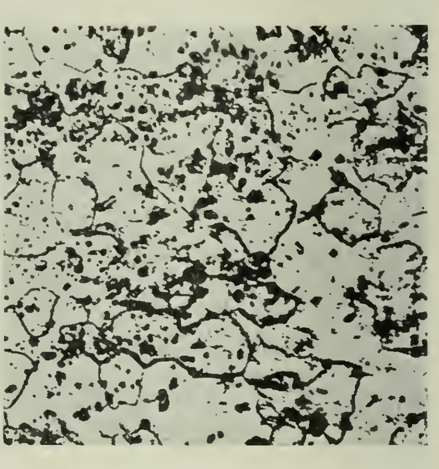
Shore H. N.—6.0. Reduction—77.7 per cent. Sixteen-gauge sheet; after five-minute exposure at 350° C.; × 100.

FIG. 23.



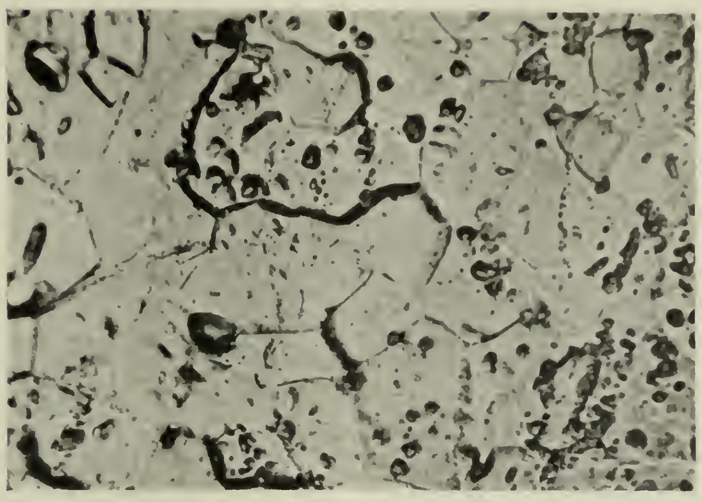
Shore H. N.—6.0. Reduction—77.7 per cent. Sixteen-gauge sheet; after five-minute exposure at 350 °C.; × 250.

FIG. 24.



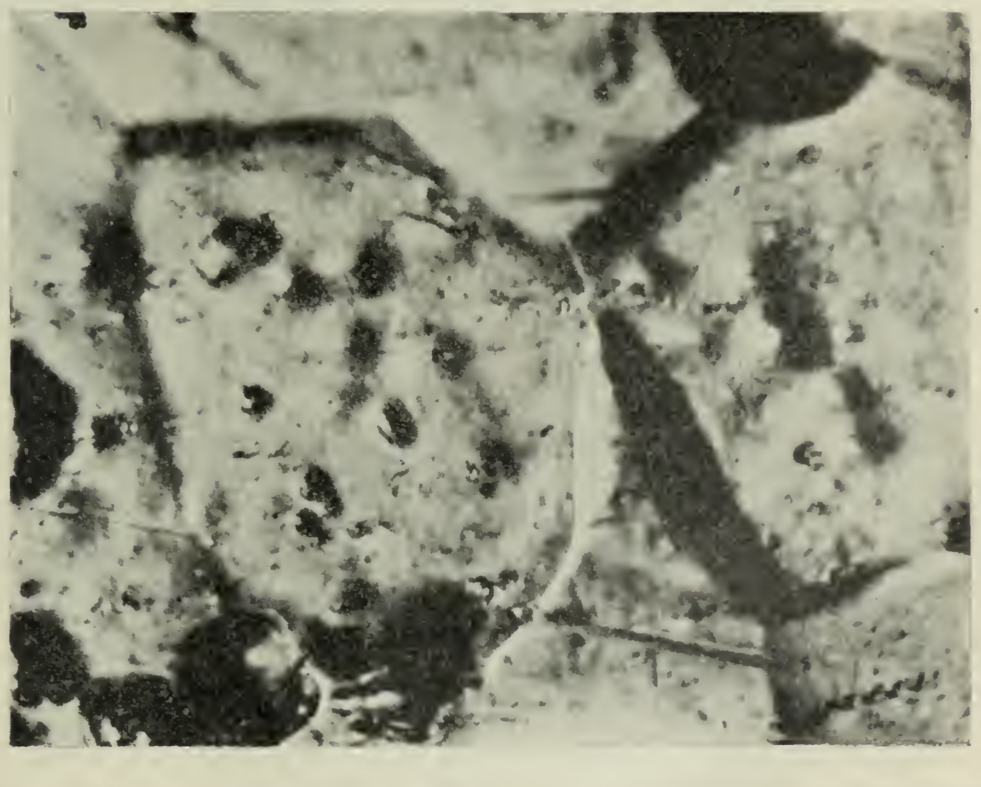
Shore H. N.—5.0. Reduction—77.7 per cent. Sixteen-gauge sheet; after four-hour exposure at 525° C.; × 100.

FIG. 25.



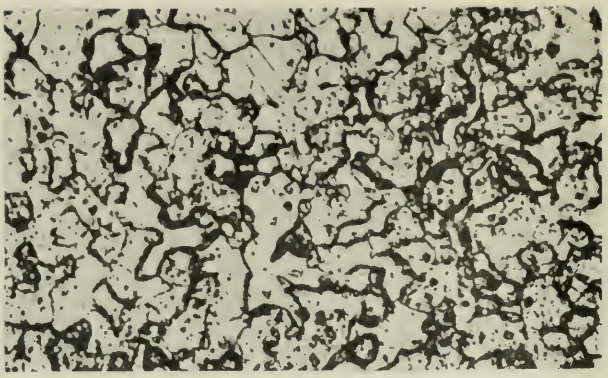
Shore H. N.—5.0. Reduction—77.7 per cent. Sixteen-gauge sheet; after four-hour exposure at 525° C.; × 100.

FIG. 26.



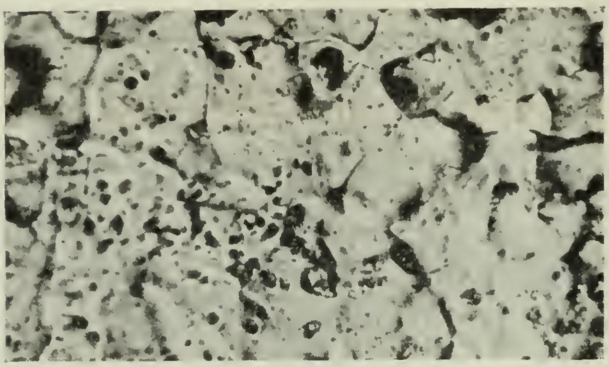
Shore H. N.—5.0. Reduction—77.7 per cent. Sixteen-gauge sheet; after four-hour exposure at 525° C.; × 1000.

FIG. 27.



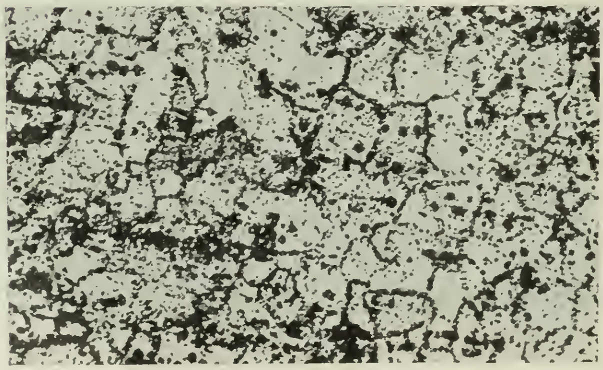
Shore H. N.—5.5. Reduction—80.0 per cent., approximately. Seventeen-gauge sheet; after 30-minute exposure at 400° C.; × 100.

FIG. 28.



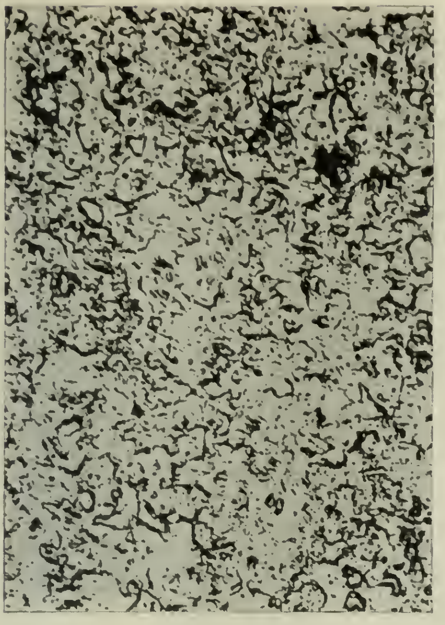
Shore H. N.—5.5. Reduction—80.0 per cent., approximately. Seventeen-gauge sheet; after 30-minute exposure at 400° C.; × 250.

FIG. 29.



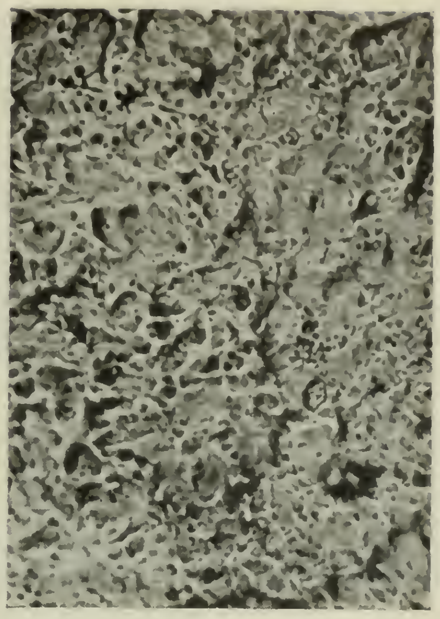
Shore H. N.—5.0. Reduction—80.0 per cent., approximately. Seventeen-gauge sheet; after 30-minute exposure at 550–575° C., and cooled with the furnace; × 100.

FIG. 30.



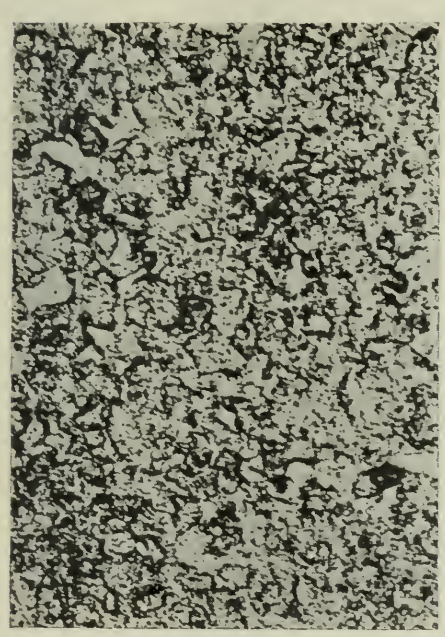
Shore H. N.—5.0. Reduction—82.6 per cent. Eighteen-gauge sheet; after two-minute exposure at 350° C.; × 100.

FIG. 31.



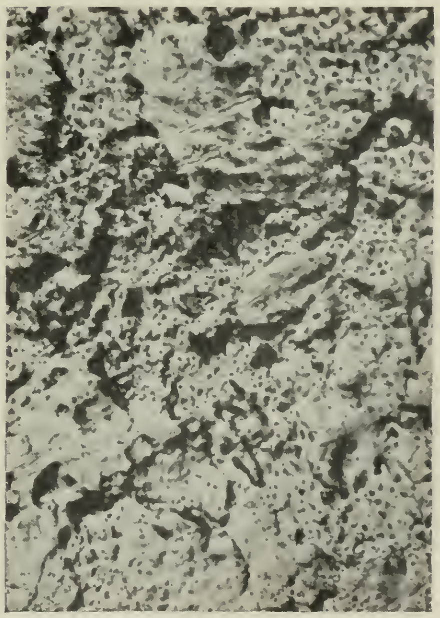
Shore H. N.—5.0. Reduction—82.6 per cent. Eighteen-gauge sheet; after two-minute exposure at 350° C.; × 250.

FIG. 32.



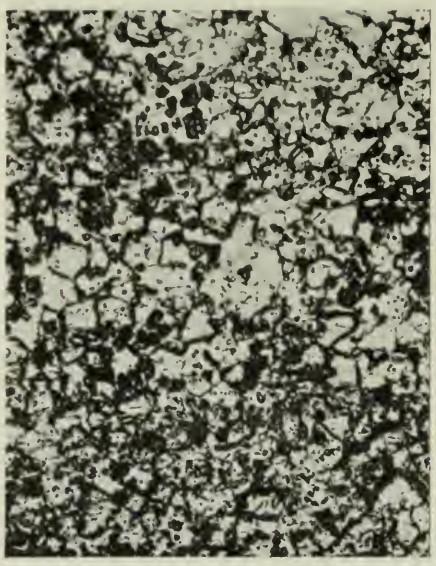
Shore H. N.—5.0. Reduction—86.0 per cent. Twenty-gauge sheet; after two-minute exposure at 350° C.; × 100.

FIG. 33.



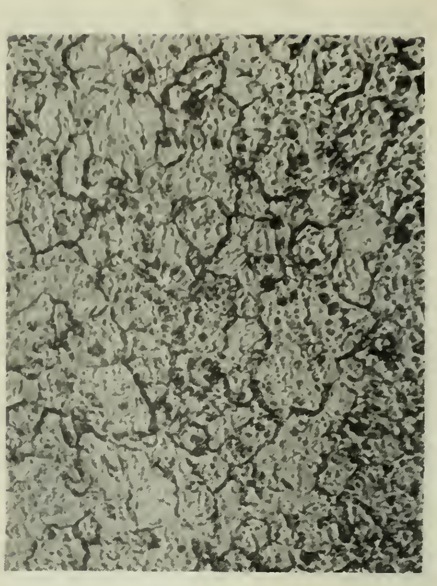
Shore H. N.—5.0. Reduction—86.0 per cent. Twenty-gauge sheet; after two-minute exposure at 350° C.; × 250.

FIG. 34.



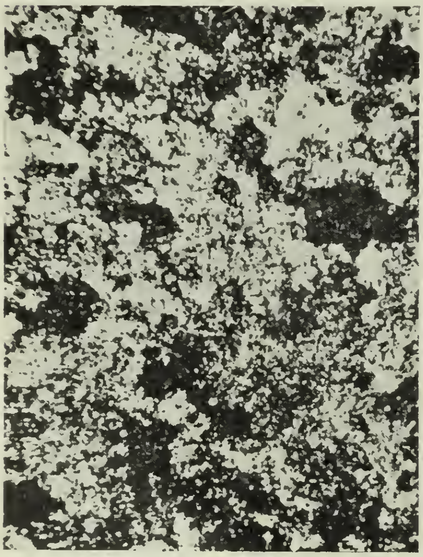
Shore H. N.—4.0. Reduction—86.0 per cent. (?); was half hard. Twenty-gauge sheet; after four-hour exposure at 525° C.; × 100.

FIG. 35.



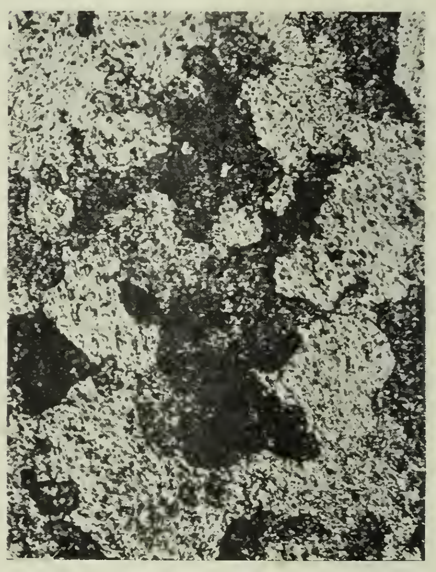
Shore H. N.—5.0. Reduction—86.0 per cent. Twenty-gauge sheet; after 30-minute exposure at 550–575° C., and cooled with the furnace; × 125.

FIG. 36.



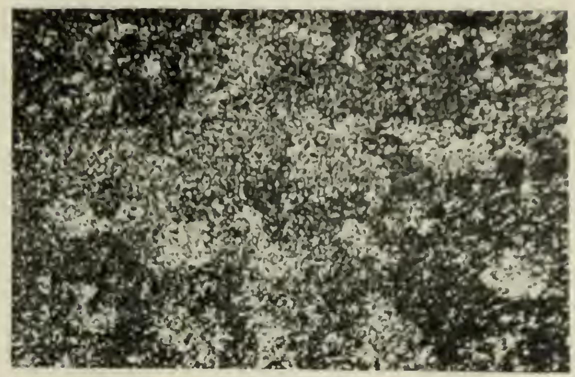
Shore H. N.—3.5. Reduction—88.0 per cent. Twenty-two gauge sheet; after 24-hour exposure at 370 °C.; × 50.

FIG. 37.



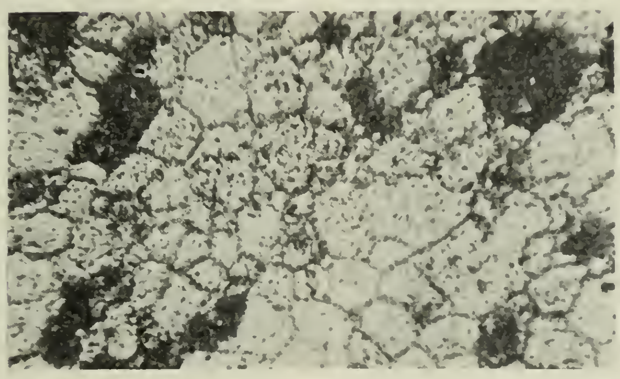
Shore H. N.—3.5. Reduction—88.0 per cent. Twenty-two gauge sheet; after 24-hour exposure at 370° C.; × 100.

FIG. 38.



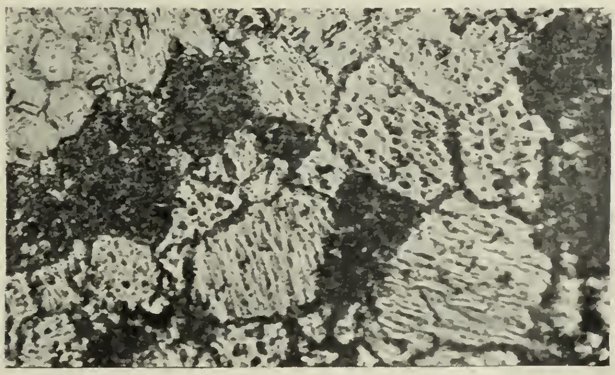
Shore H. N.—4.0. Reduction—90.5 per cent. Twenty-four gauge sheet; after 10-minute exposure at 400° C.; × 100.

FIG. 39.



Shore H. N.—5.0. Reduction—92.7 per cent. Twenty-six gauge sheet; after 30-minute exposure at 550–575° C., and cooled with the furnace; × 75.

FIG. 40.



Shore H.N.—5.0. Reduction—92.7 per cent. Twenty-six gauge sheet; after 30-minute exposure at 550–575° C. and cooled with the furnace; × 125.

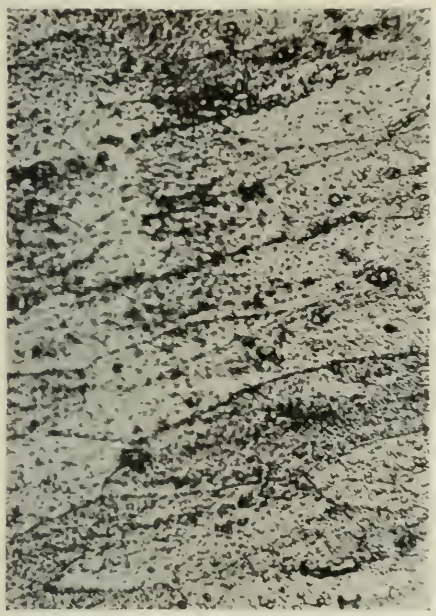
to 6, and there has been alteration in microstructure, but no complete recrystallization. Figs. 19 and 20 show the alteration in microstructure resulting from a 10-minute exposure at 400°C. for so-called half-hard sheet; such sheet is manufactured by rolling cold within about two gauge numbers of the finished gauge and then annealing so as to make it dead soft; it is then finished to gauge with a few passes in a finishing mill. It will be seen that there is a greater tendency toward recrystallization here than in the previous case. A micrograph in Fig. 21 is that of cold-rolled 14-gauge sheet after a 24-hour exposure at 370°C.

Annealings conducted on 16-gauge cold-rolled aluminum sheet with five-minute exposures at 350°C. and four-hour exposures at 525°C. give results in conformity with previous experience. The scleroscopic drop in the former instance was from 15 to 6, and in the latter from 15 to 5, but the samples annealed for the longer time and at the higher temperature were practically equiaxed, whereas the short exposure did not so result. It is now shown beyond any possibility of a doubt that the greater part of the softening occurs very rapidly in hard-worked aluminum, and to effect *complete* softening may take a very long time, depending upon the temperature. Comparison of Figs. 22 and 23 with Figs. 24, 25, and 26 should be made. Figs. 27, 28, and 29 show the internal changes set up by annealing 17-gauge sheets for 30 minutes at 400°C., and annealing for 30 minutes at 550–575°C. and cooling with the furnace, respectively. In the latter case, equiaxing has taken place, but in the former while there has been an alteration in microstructure it is not marked. In Figs. 30 and 31 are micrographs of 18-gauge aluminum sheet after a two-minute exposure at 350°C.; the percentage of reduction was 82.6 and the scleroscopic drop from 14 to 5; as in the above short exposures, there has been practically complete softening without recrystallization.

Exposures made on 20-gauge sheet for two minutes at 350°C. show the microscopic results in Figs. 32 and 33; Fig. 34 is the same metal after a four-hour exposure at 525°C.; and Fig. 35 is the same metal after annealing for 30 minutes at 550–575°C. and cooling with the furnace. It scarcely needs any clearer evidence than that so far given to show that the recrystallization of aluminum is exceedingly sluggish. Figs. 36 and 37 show the microstructure of 22-gauge sheet after a 24-hour exposure at 370°C. Fig. 38 is a micrograph of 24-gauge sheet after a 10-minute exposure at 400° C.; while Figs. 39 and 40 are micrographs of 26-gauge sheet, percentage of reduction 92.7, after heating for 30 minutes at 550–575° C. and cooling with the furnace; in the latter, recrystallization is complete, and there has been grain growth.

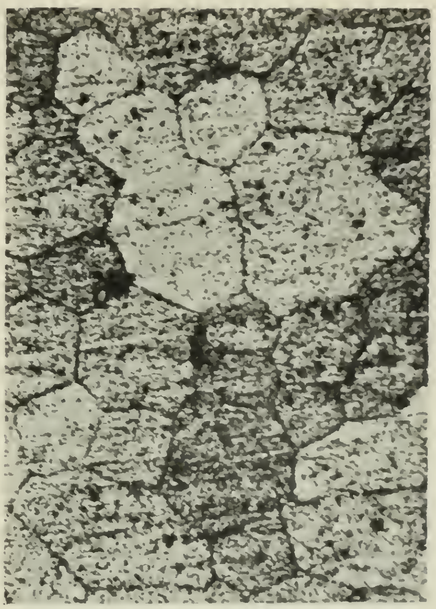
Softening of Aluminum Without Recrystallization.—From the foregoing it is readily apparent that reorientation and grain growth are not cogent factors in the softening of cold-worked aluminum, and it is necessary to look elsewhere for the explanation of the scleroscopic drop, 14–15 to 4–5. Before making any inquiry into that, however, it may be advisable to reproduce micrographs showing perfect equiaxing and grain growth in sheet aluminum, to which I have briefly referred in another place (54). Fig. 41 is a micrograph of a sample of 16-gauge aluminum sheet, the history of which appears to be this: the grains had been equiaxed on anneal and then elongated by strain (note elongated grains in Fig. 41). Fig. 42 is the same metal after annealing for 15 minutes at 540°C. and cooling with the furnace. In the same way, Fig. 43 is typical of the structure of a 16-gauge

FIG. 41.



Sixteen-gauge sheet; as received; elongated grains; × 215.

FIG. 42.



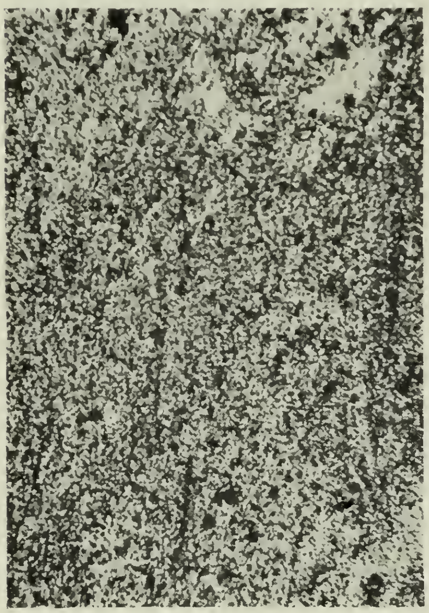
After annealing sheet in Fig. 41; 15-minute exposure at 540° C. and cooled with the furnace; × 100.

sample which had a Shore hardness of 8 as received, while after an exposure of 15 minutes at 540° C., followed by furnace cooling, the microstructure was as shown in Fig. 44. According to this, then, it appears that it is easier to recrystallize deformed aluminum on heating where there is the lesser amount of the amorphous phase. In other words, it seems that the amorphous phase is reluctantly transferable to the crystalline, in aluminum, and the change

$$\text{Amorphous} \longrightarrow \text{Crystalline}$$

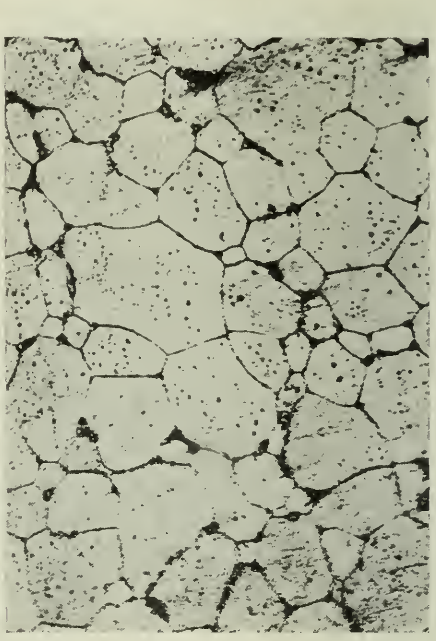
proceeds very slowly. Compare this now with the rapid recrystallization of copper, where an exposure for a few minutes or even seconds at 600–700° C. is sufficient to result in quite complete recrystallization. Whatever may be the explanation of why the amorphous phase of aluminum has such remarkable thermal stability is not readily apparent.

FIG. 43.



Sixteen-gauge sheet; as received; × 100.

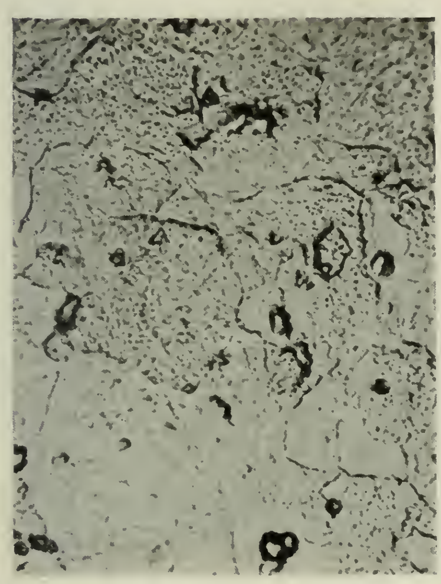
FIG. 44.



After annealing sheet in Fig. 43; 15-minute exposure at 540° C. and cooled with the furnace; × 100.

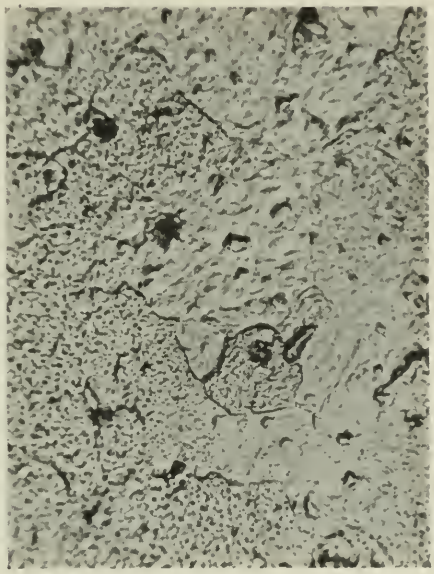
The view has been put forward by Howe (31) that stress relief and grain growth are not likely to contribute markedly to the softening resulting from heating deformed metal; that reorientation may be a contributory factor, but not the chief one; and that the reabsorption of the amorphous sheaths enclosing the fragments of grains, and a progressive change in the condition of these sheaths of the crystalline metal in those fragments are possibly important factors. Lest there be any possible doubt as to the interpretation of the micrographs in connection with the term "recrystallization," it is construed to mean reorientation and at least incipient grain growth; it is difficult, if not impossible to say just where the growth commences. There is no recrystallization in the instances cited above where short exposures bring about practically complete softening; there is unquestionably a change in the microstructure. The extreme difficulty in etching aluminum may, to a subordinate extent, account for some of the present trouble, but a comparison of the micrographs in Figs. 18, 20, and 26, under oil immersion, should suffice to remove any doubt as to the contention submitted. The effect of silicon and iron, as yet imperfectly understood, may be to retard growth, since it is conceivable that $FeAl_3$ might act as an obstruction.

FIG. 45.



Hot-rolled slab; average structure; × 215.

FIG. 46.

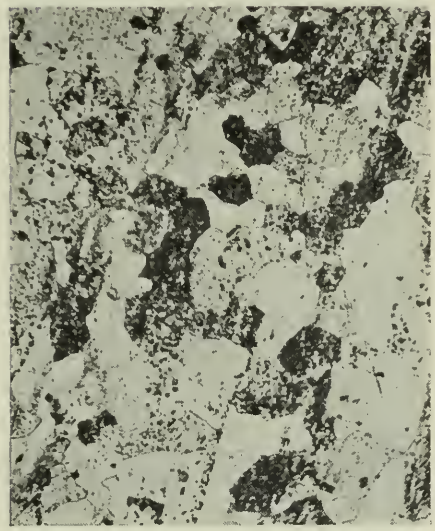


Hot-rolled slab; distortion due to cold-shearing; × 215.

VI. EXAGGERATED GRAIN GROWTH IN ALUMINUM.

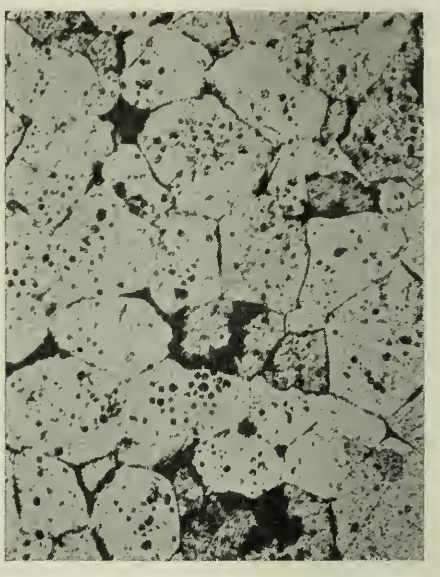
Exaggerated growth in certain parts of a sample of metal which has had differential strain has been observed by Charpy, Le Chatelier, Sauveur, Chappell, Jeffries, *et al.* Observations made have shown that local deformation such as results from a Brinell ball impression gives rise to exceedingly large grains in certain parts of the deformed area on annealing; this exaggerated growth has also been shown for strained tensile bars of iron. Space does not permit extended review of the above observations, nor is there any necessity for such review since the facts are now well known. In another place (34), I have called attention to certain recrystallization and grain growth phenomena in hot-worked aluminum, which had been differentially strained by cold shearing prior to annealing. Chappell's excellent paper (33), which has been quoted many times, described exaggerated growth in deformed steel and iron where the deformation was the result of Brinnell impression and tensile strain. In the present section of this paper, description is given of exaggerated growth in aluminum, of the above analysis where the deformation was the result of cold shearing; this shearing set up differentially strained areas within a given sample.

FIG. 47.



Centre of microsection; after 10-minute exposure at 595° C.; × 50.

FIG. 48.



Centre of microsection; after 60-minute exposure at 595° C.; × 50.

Description of Experiments.—An aluminum slab, which had been hot rolled to 0.25-inch thick, was cold sheared along one edge with a mechanical power shear which cut the slab at a stroke. The force of shearing set up strain along the edge of the slab, and the amount of strain was greatest near the edge and diminished in intensity in a direction perpendicular to the face of the sheared edge. The Shore hardness of the slab was 5, indicating practically dead-soft metal, although hot work had been done upon it; as just mentioned, the finishing was hot, probably in the neighborhood of 300–350° C., but this temperature is below the equiaxing temperature for aluminum so treated. The cold shearing caused local deformation and differential strain, the former occurring adjacent to the edge where the shear blade passed, and the latter varying in intensity inwards towards the mass of the metal. Microsections, taken from along the sheared edge, were exposed to heat for the times and temperatures given in Table II. Micrographs in Figs. 45 and 46 show the internal structure in the centre of the microsections and near the sheared edge, respectively. Grain boundaries are distinct in both micrographs, but the effect of work is evident, and the structure in Fig. 46 is more distorted than in Fig. 45 because of the strain near the edge. Figs. 47 to 58 inclusive illustrate the effects of annealing at various temperatures.

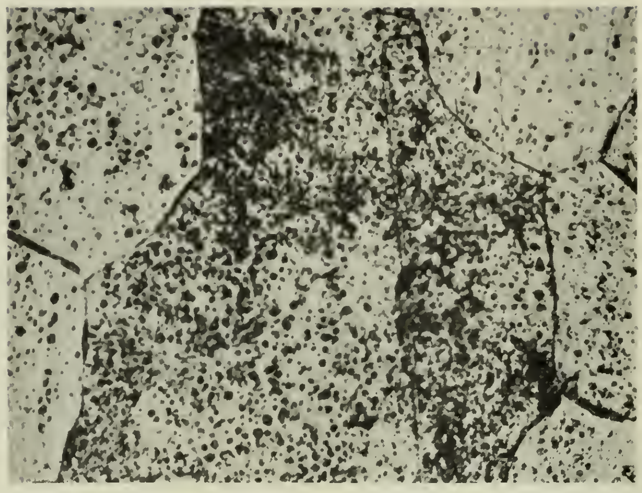
TABLE II.

Exaggerated Grain Growth in Aluminum.

Refer to figs.	Heat treatment		Remarks
	Time in mins.	Temperature in degrees C.	
45, 46			As rolled.
47, 49	10	595	Not completely recrystallized.
48, 50	60	595	Fully recrystallized.
51, 52, 53, 54	240	595	Fully recrystallized.
55, 56	10	540	Not completely recrystallized.
	60	540	Fully recrystallized.
57, 58	10	485	Grain growth in part of section.
	60	485	Grain growth in part of section.
	10	425	None of these sections was recrystallized; there was no grain growth; the effects of annealing were apparent under the microscope.
	60	425	
	10	370	
	60	370	
	10	315	
	60	315	

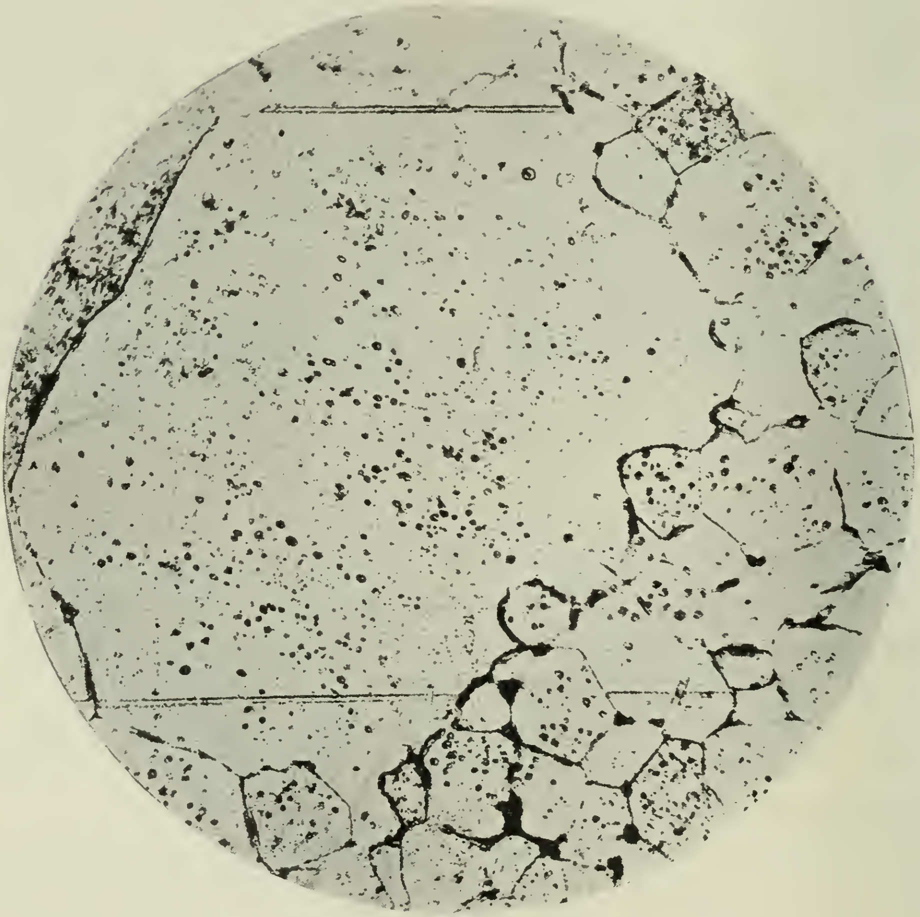
Turning now in detail to the changes in microstructure resulting from the heat treatment let us consider micrographs in Figs. 45, 47, and 48. Fig. 45 is the structure of the metal as

FIG. 49.



Enlarged grains in the portion of critical strain; after 10-minute exposure at 595° C.; × 50.

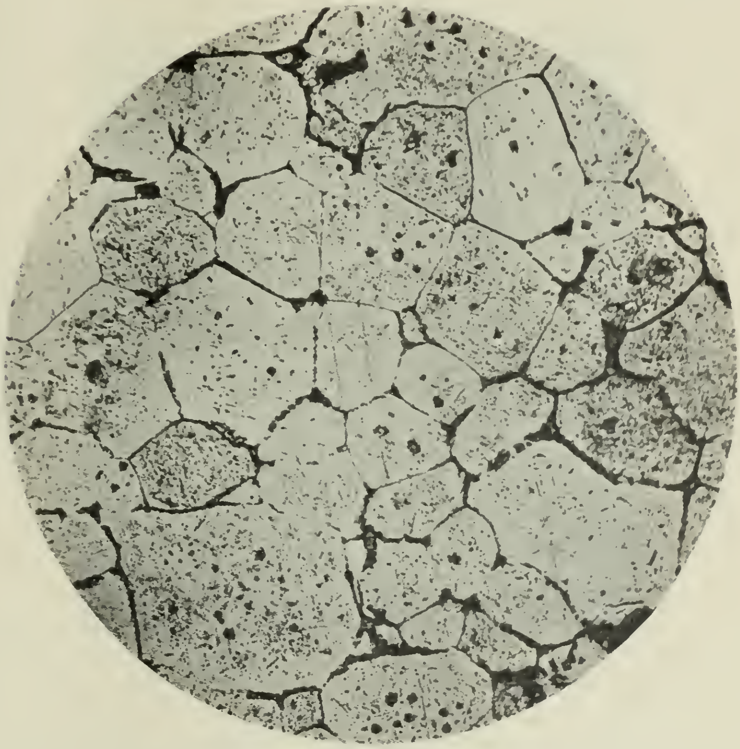
FIG. 50.



Juncture of large and small grains; after 60-minute exposure at 595° C.; × 50.

rolled, showing relatively small grains and distortion due to the hot work; the magnifications should be noted, since they were taken so as to best show the structure. Fig. 47 was taken at the centre of the microsection after an exposure of 10 minutes at 595°.C.; recrystallization is almost complete. Fig. 48 is a micrograph of the metal after a 60-minute anneal at the same temperature; recrystallization is complete and grain growth marked. Grains in the latter instance are about twice as large as in the former. Enlarged grains were found in the same microsection as Fig. 47 was taken from, at a point about midway between the edge and the centre; thus Fig. 49 shows these enlarged grains resulting in part of a section after a 10-minute exposure at 595°C. Fig. 47 shows the almost completely recrystallized structure in the same section where the strain was less. Fig. 50 shows very well the enlarged and small grains resulting from differential strain and a subsequent exposure of 60 minutes at 595°C.; the relatively large space bounded by the small grains at the right-hand side of the micrograph and by the slightly darkened portion of a grain at the left-hand side is a single grain.

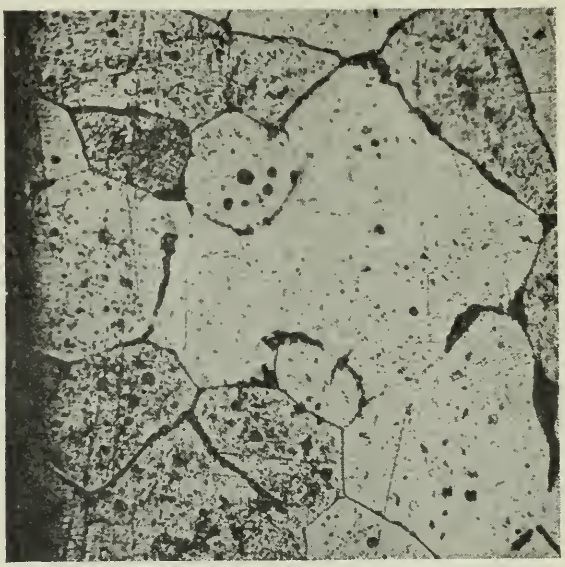
FIG. 51.



Centre of microsection; after four-hour exposure at 595° C.; ×50.

Fig. 51 is a micrograph of a sample exposed for four hours at 595°C.; beautiful allotriomorphic grains have resulted from this treatment, and they are larger than those shown in Fig. 48, where the anneal was for 60 minutes at the same temperature. The grain size of the former was 26 per sq. mm., and of the latter 34 per sq. mm. Enlarged grains were found at the edge of the same microsection where the strain had been greatest, as is shown in Fig. 52. The micrographs shown have indicated three zones, with as many sizes of grains in a section: *viz.*, (1) a zone of least strain where recrystallization proceeds slowest; (2) a zone of greater strain where recrystallization proceeds fastest; and (3) a zone of greatest strain where recrystallization is slower than in (2), but faster than in (1). Zone 1 is located farthest from the edge where the shear blade passed; zone 2 is approximately midway between zone 1 (at the centre of the section) and the edge; and zone 3 is right at the edge and extending for about one-sixteenth of an inch inwards towards the centre. Still more conclusive evidence, if possible, showing the deformation zones, is the micrograph in Fig. 53, unfortunately scratched, which shows three sizes of grains from edge to centre; the grains of fairly large size, in the upper third of the micrograph, represent the structure of the metal at the edge; the considerably enlarged

FIG. 52.

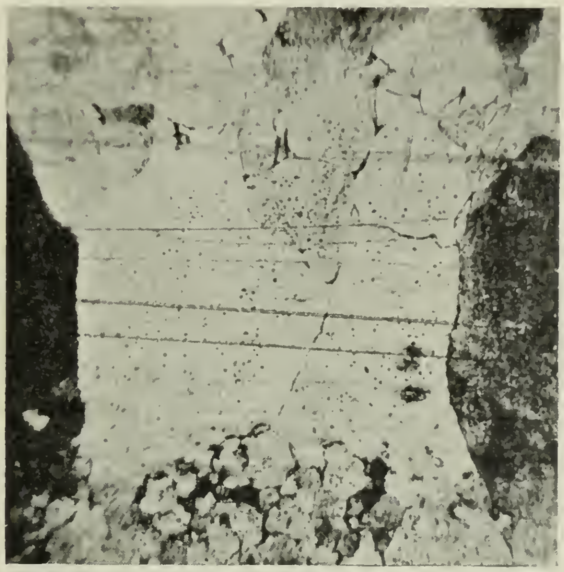


Enlarged grains at edge of microsection; after four-hour exposure at 595° C.; × 50.

grains, in the centre third, represent a portion of the metal a little farther away from the edge and towards the centre; while the relatively small grains, in the lower part of the micrograph, represent the average structure of the metal in the centre of the section. In the foregoing, the sample was exposed for four hours at 595°C.

Considering these facts and the micrographic evidence, it follows that the grains at the edge have not grown to the size of the grains immediately adjacent for one or a combination of the following reasons:

FIG. 53.

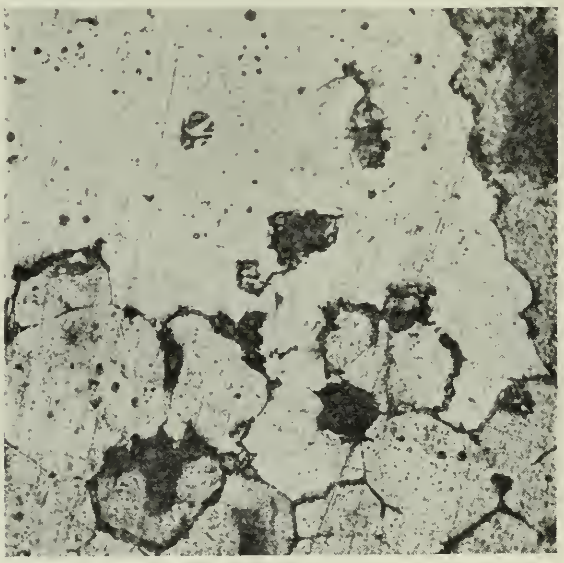


Three sizes of grains in section; after four-hour exposure at 595° C.; × 20.

(1) Metal was not available on the edge side of the microsection to allow grain growth by migration outwards;
(2) The largest grains grew in both directions, toward centre and edge, at the expense of the adjoining grains; and
(3) The largest grains were located at the point of critical strain for the temperature employed, and hence the largest grains resulted there.

Under the conditions of these experiments, it was invariably observed that wherever there had been differential grain growth, those grains at the edge were smaller than ones a little farther in from the edge towards the centre of the microsection, and yet larger than those in the centre. In other words, those grains at a point which has been strained intermediately between two extremes grew to be the largest. Figs. 55 and 56 are micrographs showing the alteration in internal structure accompanying annealing for 10 minutes at 540°C., while in Figs. 57 and 58 are shown the results of a 10-minute exposure at 485°C.; in both anneals, it will be seen that differential grain growth has ensued, although the metal in the centre of the microsections is apparently not fully recrystallized in either case. At the point of critical strain, however, enlarged grains have developed bordered by small grains approximately equiaxed. Although the amount of strain given to the metal by the cold shearing is indefinite, *i.e.,* it could not be measured in units, the effects of temperature on such strain are recorded, and the exaggerated growth following such strain on annealing is shown beyond any doubt.

FIG. 54.

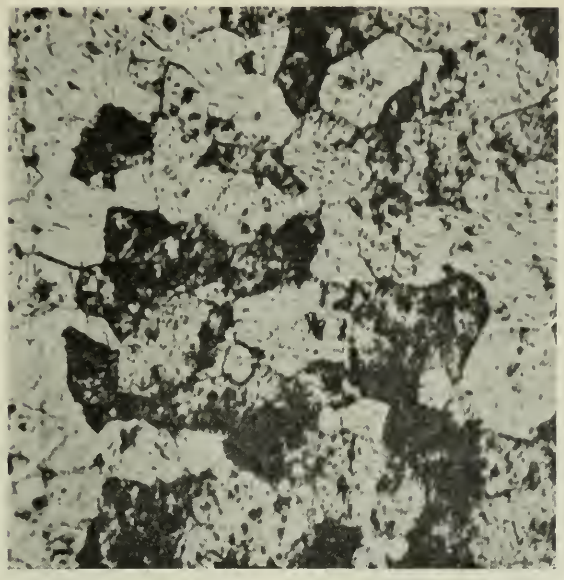


Juncture of large and small grains; after four-hour exposure at 595° C.; × 50.

VII. SLIP BANDS IN ALUMINUM.

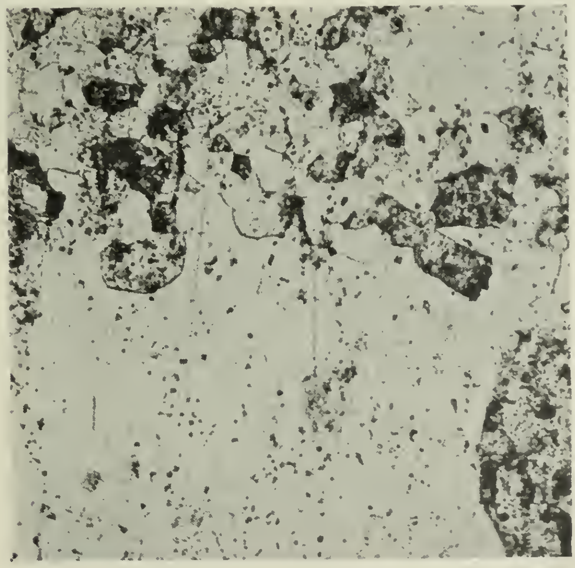
When substantially pure aluminum, or one of its ductile alloys, is strained, slip bands are formed, but no twinning as the result of direct mechanical strain has so far been observed. The origin of slip bands arises in the sliding or slip in the crystals of a ductile metal when plastic deformation acts, and the slip bands make themselves evident as fine, straight or curved, lines on the faces of the individual crystals. They may be very conveniently developed by polishing and etching a sample of metal and then subjecting it to stress exceeding the elastic limit. Slip bands in aluminum and two of its alloys have been developed by direct compres-

Fig. 55.



Centre of microsection; after 10-minute exposure at 540° C.; × 100.

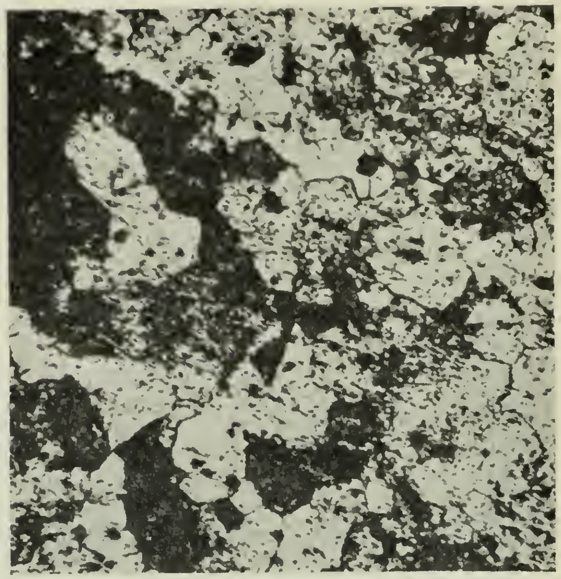
Fig. 56.



Juncture of large and small grains; after 10-minute exposure at 540° C.; × 100.

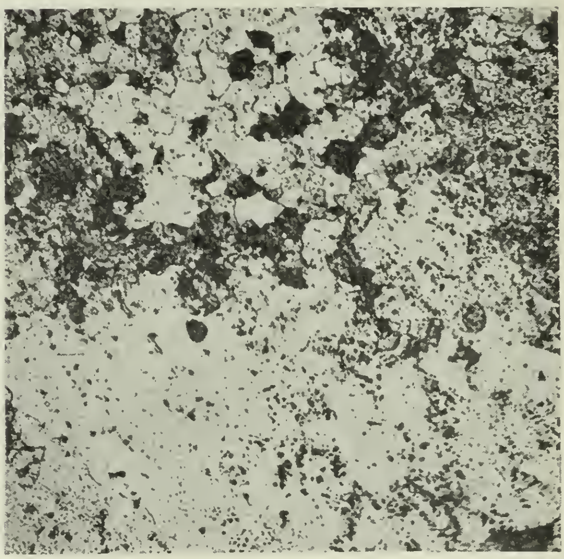
sion of previously polished and etched samples; micrographs are shown in Figs. 59 to 64. Under the microscope, a slip band is seen black under vertical illumination, since the surface is not horizontal and does not reflect the light vertically back into the

FIG. 57.



Centre of microsection; after 10-minute exposure at 485° C.; × 100.

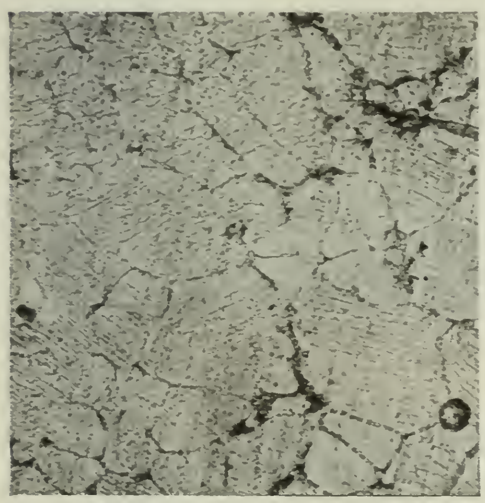
FIG. 58.



Juncture of large and small grains; after 10-minute exposure at 485° C.; × 50.

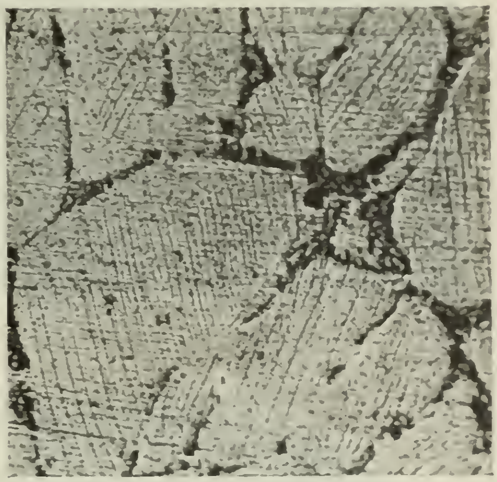
tube of the microscope. No comprehensive discussion of the nature of slip bands is contemplated, but the main facts may be indicated. Their crystallographic direction, in certain instances, tends to show that they represent slip along crystallographic planes; Osmond, however, interpreted only straight slip bands as representing crystalline motion. Slip bands are to be distinguished from Neumann bands, which are the outcrops of mechanically twinned lamellæ set up in ferrite and some other metals, *e.g.*, bismuth, by deformation. What Howe (26) calls X bands are rough striæ found on polishing and etching iron which has undergone severe plastic deformation; when ferrite is deformed so as to produce slip bands, and then repolished so as to efface the slip bands and then etched, bands may appear, which are called X bands. Their nature is unknown.

FIG. 59.



Slip bands in 1.65 per cent. Mn–Al alloy; etched with NaOH; × 125.

FIG. 60.



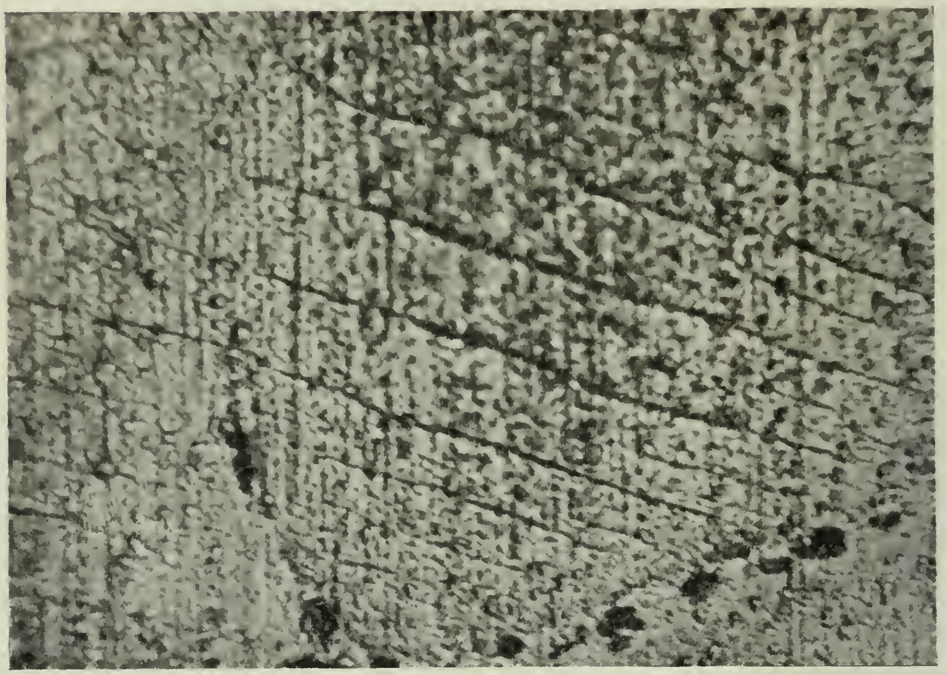
Slip bands in 1.65 per cent. Mn–Al alloy; etched with NaOH; × 250.

Figs. 59 to 61 show slip bands in the aluminum alloy containing 1.65 per cent. Mn., at various magnifications; the bands are uni-directional in any given grain. Figs. 62 and 63 show these bands in an impure aluminum sample, where two sets of bands within individual grains are found, crossing each other at an angle of approximately 65°. Bands in Fig. 64 were developed in substantially pure aluminum by severe compression; the surface of the sample was much roughened and difficult to photograph.

VIII. POLISHING AND ETCHING ALUMINUM.

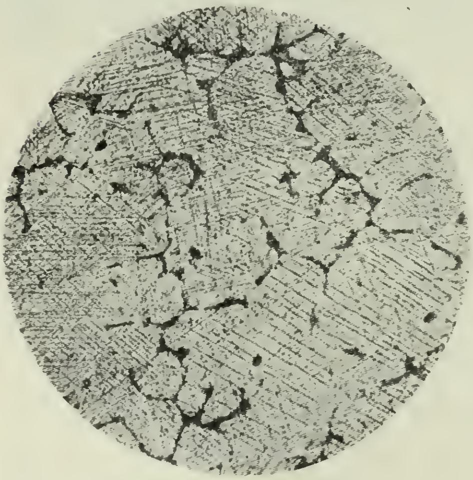
Aluminum is a difficult metal to satisfactorily polish and etch (55,60), and even when the usual precautions are observed it does not at times yield satisfactory microsections. One difficulty lies in its softness and ease of amorphization under polishing press-

FIG. 61.



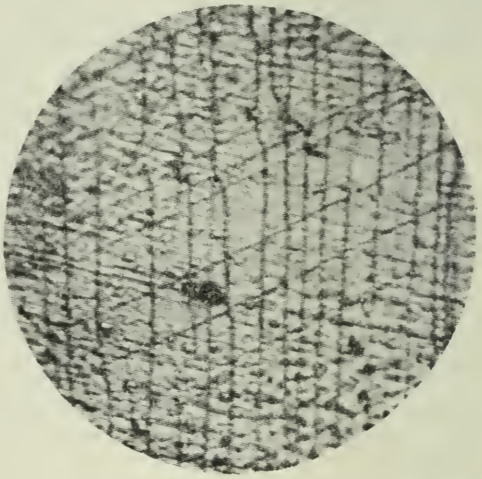
Slip bands in 1.65 per cent. Mn-Al alloy; etched with NaOH; × 1000.

FIG. 62.



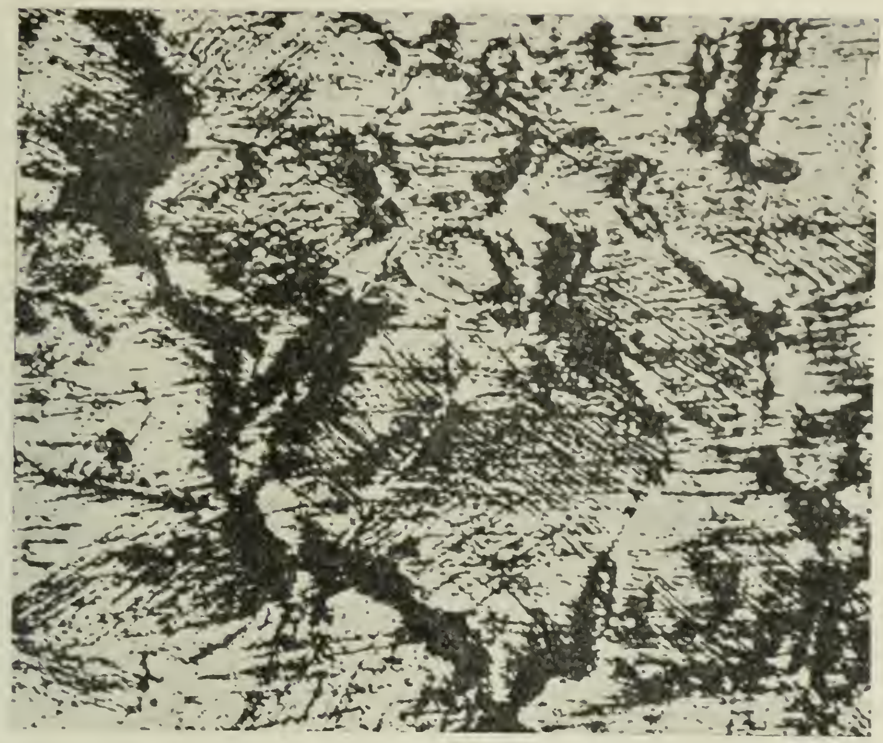
Slip bands in impure (97 per cent.) aluminum; etched with NaOH; × 125.

FIG. 63.



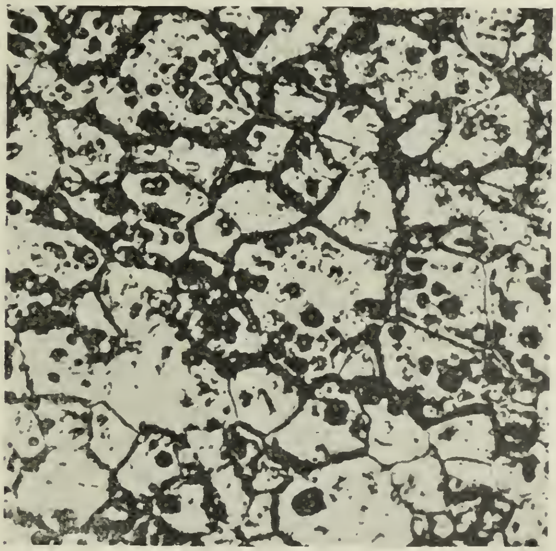
Slip bands in impure (97 per cent.) aluminum; etched with NaOH; × 1000.

FIG. 64.



Slip bands in substantially pure cast aluminum; × 200.

FIG. 65.



Etching pits in annealed aluminum; × 200.

ure, and another is the choice of an etching reagent. There have been elsewhere (55,59) described methods for the preparation of aluminum microsections, and here there will only be confirmed the statement which I have made before; *viz.*, that hydrofluoric acid will, in the majority of cases, be found the most satisfactory etching reagent for aluminum. Until some other reagent is developed, and hydrofluoric acid is not all that is desired, this will have to remain the standard etching agent for aluminum; for aluminum alloys, other reagents are at times more satisfactory. At best, aluminum is very difficult to etch (61). In the micrographs shown in the present paper, the etching was all done with hydrofluoric acid, usually about 8 per cent. in aqueous solution, unless otherwise noted. In etching with hydrofluoric acid, it is best to follow the attack with immersion in concentrated nitric acid, in order to remove the black deposit which forms and brighten the sample. When using sodium hydroxide, the usual strength employed is a 10 per cent. aqueous solution, and the etching attack is followed by immersion in either concentrated chromic or nitric acid; lately, very dilute solutions of sodium hydroxide have been employed—about 0.10 per cent. With hydrofluoric acid, aluminum tends to develop etching pits, particularly in annealed samples; etching pits, in a sample of drawn and annealed aluminum, are shown in Fig. 65.

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A Self-Adjusting Thrust Bearing. H. G. REIST. (*General Electric Review*, vol. 21, No. 7, July, 1918.)—Thurst bearings for supporting the heavy loads of water-wheels and electric generators driven by them are now very widely used. The difficulties in the fitting and use of plate bearings are much aggravated, as the load is increased on account of the large over-all dimensions of the supporting plate. It is true that the surface can be fitted quite accurately by machine, but there have been cases where the surfaces have been turned slightly conical, with the result that they bore hard on the inner or outer edge. The deflection of the supporting collar in the shaft may allow the runner to be slightly dished, or there may be a deflection of the supporting surface, thereby dishing the babbitted seat or causing one side to become lower than the other. The self-adjusting spherical seat, provided to correct some of these difficulties, is of doubtful value on large bearings on account of the great frictional resistance which must be overcome to make it shift.

Thrust-bearing surfaces are usually scraped to each other, or to a surface plate, to avoid dangerously high spots; but since the oil-film is of the order of two ten-thousandths to three ten-thousandths of an inch in thickness, the difference in level must be smaller than these values. This work must usually be done without load, and no matter how carefully it is done, when the bearing is loaded the parts will not fit each other because of deflection.

A careful study of the above difficulties led to the design of a flexible bearing surface pressed against the runner by springs. It seemed that this would prevent the possibility of undue pressure at any point and compel each element of the surface to carry its share of the load. On trial this solution proved satisfactory.

In a typical design for vertical shaft machines, the bearing consists of a runner of a special grade of cast iron resting on a thin steel ring which has a babbitted surface. The babbitted stationary ring, in turn, rests on short helical springs and is held against rotation by dowel pins. A saw-cut through one side eliminates any tendency of the ring to "dish" with a change in temperature. The springs ordinarily used are of one-half inch round wire, with an outside diameter of two inches, and a free length of one and one-half inches. Under load the springs close about one-sixteenth of an inch, and the total pressure is well distributed. By this means it is possible to avoid excessive pressures at any point. Thus it is safe to run with much higher average pressure than when there is no definite limit to the pressure which may occur over a small area.

A TRIBUTE.

SAMUEL PIERPONT LANGLEY: PIONEER IN PRACTICAL AVIATION.*

BY

HENRY LEFFMANN,
Member of the Institute.

It may be safely assumed, I think, that mankind from its earliest period of self-consciousness had aspirations of flying. In primitive times birds were more abundant and varied than at present, at least in civilized countries, and the ease and grace of their flight must have profoundly impressed the rudest races. The legend of Icarus and his waxen wings is one of the expressions of this feeling. Among the world-wide and very ancient witchcraft legends we find the gift of flying a usual feature. In the later phases of these superstitions, especially as they appear in English-speaking nations, the highly unromantic method of broomstick flight is eminently characteristic.

Notwithstanding all aspirations, no practical method of flight by human beings can be demonstrated until 1783, when the brothers Montogolfier sent up a hot-air balloon. Hydrogen gas was soon after substituted for air, and the balloon in substantially its present form was produced. The standard form of balloon, however, does not fly in the full sense of the word; it simply floats in the air, subject to the currents thereof. Its modification, the dirigible, which has acquired such prominence in recent years, especially in the form known as the Zeppelin, has solved some of the problems of flight, but it is an expensive, complicated and untrustworthy form, and has very limited practical application.

All creatures that fly are heavier than air, and this leads to the view that it will be by the method they use, namely, reaction upon the air as a material substance, that true flight will be obtained.

This was Langley's view, and it is to his honor that he insisted on this principle, and pointed the way, both in theory and practice, to its accomplishment. It is the purpose of this paper to summarize his main work, and to present his claims to the gratitude and admiration of the American people. The history of the later years of his life, when he was approaching the solution of the problem, in fact, had attained it, is one of the tragedies of science, and a painful reminder of the gap that still exists between the true scientist and the mass of the community, even in highly civilized lands.

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* Presented at a meeting of the Alumni Association of the Institute, held Thursday, October 31, 1918.

It would, however, be inaccurate to claim for Langley, absolute priority for the idea that a heavier-than-air machine can be made to fly. To think of an invention is a simple mental effort, and there are few of the great inventions or discoveries of the modern time that cannot be found foreshadowed in the records of the past. A Greek poet describes in set terms the invention of submarine warfare, when Scyllus and his daughter, expert swimmers, dived at the sides of Xerxes' ships, cut the mooring cables, and thus caused many ships to drift to their destruction.

About the time of the discovery of America, that remarkable and versatile genius, Leonardo Da Vinci, wrote an essay on the flight of birds, and referred to the possibility of human flight. I have not been able to consult the original essay, but notes thereon, by Da Vinci, have been translated,[1] and from this text I make a few selections.

"I have divided the *Treatise on Birds* into four books: of "which the first treats of their flight by beating their wings; the "second of flight without beating the wings, and with the help of "the wind; the third of flight in general, such as that of birds, bats, "fishes, animals and insects; the last of the mechanism of this "movement." * * * * *

"Remember that your bird should have no other model "than that of the bat, because its membranes serve as armor, or "rather as a means of binding together the pieces of its armor, "that is the framework of the wings. * * * * The bat is "aided by the membrane which binds the whole together, and is "not penetrated by the air."

"Dissect the bat, study it carefully and on this model con-"struct the machine.

"The bird I have described ought to be able by the help of "the wind to rise to a great height, and this will prove to be its

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[1] Leonardo Da Vinci's Note Books. Translated by Edward McCurdy, A.M. London, Duckworth and Company, 1906.

"safety; since even if all the above-mentioned revolutions were "to befall it, it would still have time to regain its equilibrium; pro-"vided that its various parts have a great power of resistance, so "that they can safely withstand the fury and violence of the "descent, by the aid of the defences which I have mentioned; and "the joints should be made of strong tanned hide, and sewn with "cords of very strong raw silk. And let no one encumber himself "with iron bands, for these are soon broken at the joints, or else "they become worn out, and consequently it is well not to encum-"ber one's self with them."

It will be seen from these quotations that Da Vinci's plan was to equip a man with wings to be operated by his muscles, probably those of both legs and arms, for in another note he states that the muscles of the legs are much more powerful than the ordinary work done by them requires. He did not contemplate the use of machinery. It must be borne in mind that in that day, no powerful, portable prime-mover was known.

Attempts have been made to credit Da Vinci with the anticipation of the modern aeroplane, but there is nothing in his essay which can justify this claim. He made a study of the flight of birds, but his inferences were not correct in some important respects, and while we may give him credit for scientific method, it is apparent that he "thought of" rather than "thought out" the problem of human flight. Langley does not appear to have been acquainted with Da Vinci's work, at least it is not quoted in any of his writings that I have consulted, and in the article in the ninth edition of the *Encyclopedia Britannica,* which is given among his references, there is no mention of Da Vinci's investigations, but these are briefly noted in the eleventh edition (article on "Flight and Flying").

Claims have been made for many experimenters and investigators, as having made flights with small machines, but definite data have rarely been furnished, and it is probable that Langley is justified in his claim that until the experiments in May, 1896—to be later described—no true flight of a heavier-than-air machine had been made.

Machines based on the principle that Da Vinci discussed have been built and operated by several investigators. These have been mostly "gliders," enabling the person to make a slow, inclined descent from a high point, but not conferring the power of rising from the ground or alighting at a given place at a considerable distance from the starting point. A glider of this type was constructed by Otto Lilienthal, and operated many times in the year 1896. He was killed by the upsetting of his machine in a gust. Percy Pilcher made many such flights in 1899, but also lost his life in an accident. Octave Chanute, however, made over a thousand flights without injury to himself. These operators sometimes made their flight by running the machine, or having it pulled, against the wind and thus rising from the ground much the same way as a kite is flown. It is obvious, however, that these machines do not solve the problem of flying in its important practical applications. It is also obvious that modern flying machines, whether the dirigible balloon or the aeroplane, do not act wholly on the principles of flight by the bird or insect.

It is interesting to note that in animals the ratio of wing area to weight diminishes as the weight increases. Thus, according to the *Encyclopedia Britannica*, the wing-area of the dragon-fly is, in proportion to its weight, nearly twenty-five times that of the pigeon.

Langley began his investigations in 1887, at the Allegheny Observatory. At that time he was not aware that any other investigator had accomplished anything along the lines that he was working, but he subsequently found out that A. Pénaud, an ingenious French mechanician, had made in 1872, a machine about twenty inches long resembling some of the simpler modern aeroplanes, using twisted rubber as a motive power. He had described this in a journal called "L'Aéronaute." No copy of this journal is accessible to me, but the details of Pénaud's machine with pictures are given in the memoir quoted below. Pénaud stated that he had obtained a flight of 60 meters during 13 seconds. Langley was never able to obtain such results, but states that twisted rubber has a very high potential, being much more efficient than any steel spring he tried.

From the start Langley proceeded in a truly scientific manner, studying the mathematics and physics of the problem, preliminary to construction of apparatus. His results are set forth in two publications, "The Internal Work of the Wind" and "Experiments in Aerodynamics." He discovered that the law laid down by Newton, and accepted by most mathematicians and physicists, namely, that atmospheric resistance to inclined surfaces is proportionate to the square of the sine of the angle of inclination, is not founded in fact, the resistance being really proportionate to the angle directly. The interesting story of the invention of the practical aeroplane is to be found in the ponderous quarto of over 300 pages, entitled "The Langley Memoir on Mechanical Flight," published by the Smithsonian Institution, and consisting of two papers, one mostly by Langley himself, the other by his faithful and efficient assistant, Charles M. Manly. It is from this publication that I have drawn most of the material for this essay.

Notwithstanding that the problem of flight had engaged human attention for many centuries, and had attracted all classes of persons, ranging from such a profound genius as Da Vinci to mere cranks and dreamers, yet when Langley took up the matter there were but few data available, and there was almost no one disposed to give him encouragement, tangible or sentimental. Distinguished scientists deprecated investigations into the subject. As late as 1900 a prominent astronomer and mathematician declared that it would be impossible to construct a machine capable of sustaining the weight of the largest known birds, not knowing that two of Langley's machines had already accomplished more than this. "The truly blind are those who will not see."

After several years' assiduous labor, he was able to announce that it is possible to give such velocity to inclined surfaces that bodies indefinitely heavier than air could be driven through it with great velocity. As a concrete instance, he states that a plane surface, 76.2 centimeters by 12.2 centimeters (about 1 sq. foot) weighing 500 grams, could be driven through air in absolutely horizontal flight at the rate of 20 meters per second with 0.01 horse-power. This is equivalent to a weight of 200 lbs. driven through air by 1 h.p. at 40 miles per hour.

Following up this conclusion, a number of machines were constructed and tried out, some of them, of course, quite small, others of considerable size. For all the machines he made Langley coined the word "Aerodrome," from two Greek words meaning "air runner." This word is now often used as the name for the shed in which the flying machine is stored.

In passing from very small machines in which twisted rubber or steel springs can be used—which are mere toys—to large machines which can make reasonably long flights, the question of motor became of great importance. Questions of stability, both lateral and longitudinal, also required answer. I will not enter into a consideration of stability problems. They were most carefully investigated by Langley, and involved mathematical as well as mechanical methods. It is now well known that the stability of aeroplanes has been satisfactorily attained.

When Langley began his experiments, the only motor that seemed to offer practical application was the steam-engine. This had been for a long while the only one applicable to a moving object, as is indicated by its extensive use in both land and water transportation. The steam-engine is heavy, and also requires fuel and water, so that the total weight is considerable. In the ordinary uses of it in land transportation this is not a very serious matter, for the locomotive draws best when it presses strongly on the rails, and even in water transportation, the weight of engine, fuel and water are probably of less importance than the space they occupy. Langley, in 1891, canvassed the portable motors then known. These were, in addition to steam, compressed air, liquid carbon dioxid, electric batteries, gunpowder, and the internal combustion engine. The last-named, which is now the only motor used in flying machines, was at that time but little developed, and was rejected, as were all the others except the steam-engine. The requirements were that the apparatus should be light, capable of developing steam rapidly and at considerable pressure, and using a fuel of high heating efficiency. Water-tube boilers were alone suitable, alcohol or gasoline as the fuel. Oscillating engines were used at first. Many experiments were made with boilers and with burners, and much difficulty was experienced in getting and maintaining sufficient pressure. Langley's accounts of the failures and disappointments make painful reading, but space does not permit a summary of these matters, especially as the steam-engine has ceased to be important in the field with which we are now concerned.

After many months of weary working, it was finally thought to be possible to secure a flight in the open air, and preparations were made for this. The story of the failures, disasters and disappointments that preceded the actual flight—told with much vividness in the "Memoir"—is a striking instance of the will-power and self-reliance of the inventor, and of his possessing to a high degree that characteristic of genius, "the infinite capacity of taking trouble."

After succeeding in the construction of a power-driven flying machine, two problems were presented in connection with open-air trials: a suitable locality and a method of launching. It was decided that it would be safest to launch the machine over water, as in case of a fall it would be not seriously damaged and be readily recovered. It was, of course, also advisable that the location should not be far from Washington, at which place the construction was being carried on, and should not be in a populated district. The spot chosen was a small island in the Potomac River, about thirty miles below Washington.

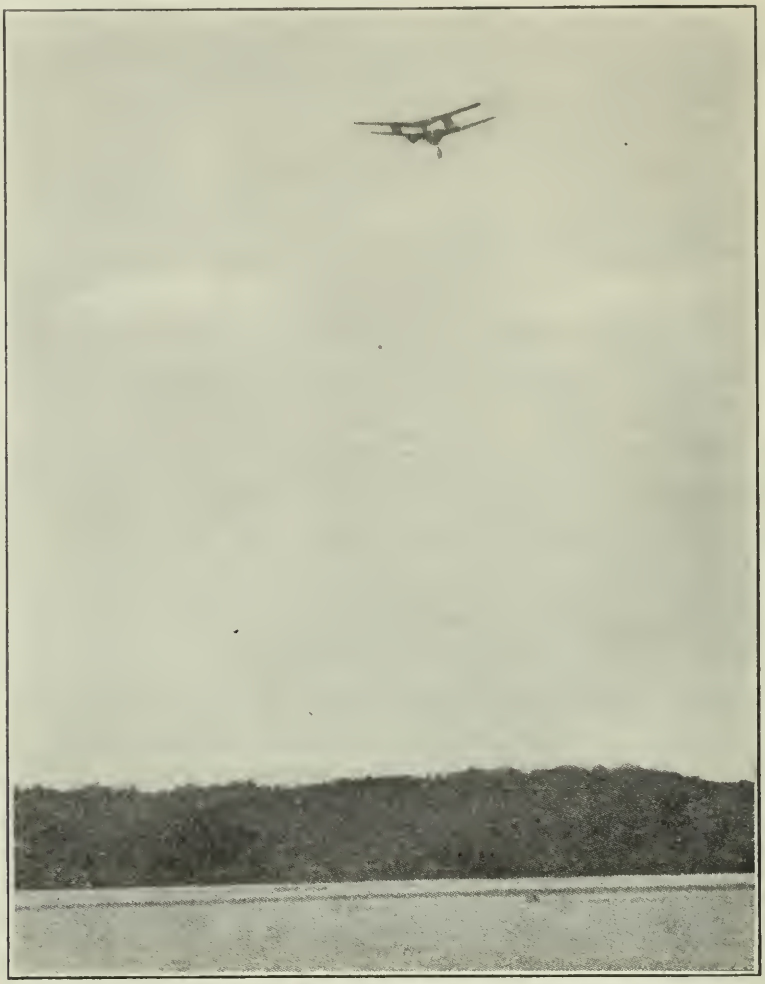
For launching the machine, a sort of house-boat was built by putting a frame room on a scow, and on the roof of this a horizontal track with releasing apparatus. The room served for storing the machine and was fitted with apparatus for repair work.

In the latter part of 1893, an aerodrome, designated as No. 4, was taken to the trial-ground, but though eight trips were made for trials, none was successful, and the year closed without any demonstration of the capacity of the machine. The year 1894 also passed without any successful flight, although a few short movements had been secured, and the machines seemed to be less erratic and the power was shown to be sufficient for the work. Little better results were obtained during 1895, but much information as to the defects of construction were obtained, so that with the opening of the following year, the problem was much nearer solution, in fact, was solved.

In the early part of 1896, two aerodromes, 5 and 6, were available, and on May 6 of that year, Langley with A. Graham Bell and several assistants were at the trial-ground. The wind was so high during the morning that no attempt at flight was made, but at 1 P.M. it had become much less active, and at 1.10, aerodrome No. 6 was launched, but owing to some entanglement with the launching apparatus, it settled directly into the water. Aerodrome 5 was then tried. At 3.05 it was launched with a steam pressure of 150 lbs., and started directly into the gentle breeze that was blowing.

The height of the launching track above the water was about twenty feet; the machine, first descended about three feet, but immediately began to rise until the midrib made an angle of about 10 degrees with the horizontal, and maintained this mostly through the entire flight. After leaving the boat, it circled to the right and moved with great steadiness, making a spiral path of two complete turns and part of a third. During the first two turns the apparatus was constantly ascending, and at the end of the second turn, had reached a height, estimated at over 75 feet. The power then began to give out and the machine slowly descended, striking the water in approximation to a "nose-dive," having been in the air 80 seconds and travelled about 3,300 feet,

FIG. 1.



Instantaneous photograph of aerodrome in flight at Quantico, Potomac River, May 6, 1896.
"Langley Memoir on Mechanical Flight." Plate 21.

which would mean a rate of about 20 miles per hour. The machine was recovered at once, and being found not injured, a second trial was made, with somewhat similar result, making three turns at a height of about sixty feet, during 91 seconds, over a path estimated as carefully as possible at 2,300 feet. Several photographs were taken during these flights.

These flights, of course, meant much to the patient inventor and his friends. For the first time in the history of the world a heavier-than-air machine had actually flown through the air and preserved its equilibrium without the aid of a guiding intelligence. Moreover, a second trial had been made, thus showing that the first was no mere accident.

It seems somewhat curious that these striking results were not immediately followed up. No explanation of the suspension of the experiments is given in the "Memoir," except to say that the inventor left for Europe, intending to be away until fall. Instructions were given to the mechanicians to remedy certain small defects in the machines.

On November 27, a trial was made of aerodome 6, but owing to the breaking of a pin, the trial was a failure. In the afternoon of the next day, a successful flight was made, the machine going in a curved path of about three-quarters of a mile in 105 seconds, a rate of about thirty miles per hour. "*Finis coronat opus.*"

Obviously the success of the aerodromes led to the thought of the construction of a man-carrying machine. Langley hesitated on account of the many duties in connection with his official relations with the Smithsonian Institution, yet the longing to take the final step was too attractive to his scientific mind and soon took possession of him. Ten years had been passed in laborious experiment, full of disheartening difficulties, and he thoroughly realized that the construction of a machine large enough to carry a man would be a mighty labor, but his spirit was no flickering flame like that of light straw, but determined and devoted to the object of science—the discovery of truth.

In undertaking the construction of a large aerodrome, Langley was much influenced by President McKinley, who had become impressed with the value of the instrument in war. It will not be necessary to set forth here the official procedures which led up to the work, but merely to state that in the latter part of 1898, an appropriation of $50,000 was made for the purpose through the Board of Ordnance and Fortification.

Langley had always recognized that one of the most important problems in a flying machine is the motor, which should be light, powerful and capable of maintaining its action for a long time on a small volume of fuel and other supplies (such as water). The internal-combustion engine, then coming into notice, was obviously the most promising form, but as he was not familiar with this apparatus, he deemed it proper to delay definite action until a satisfactory engine could be secured. After much searching, a contract was placed on December 28, 1898, for a 12 h.p. engine to weigh not more than 100 lbs., and the construction of an aerodrome for use with this engine was at once begun. Notwithstanding the amount of research that had been given to the mathematics and physics of flight of heavier-than-air machines, it was felt that the new problem required much more investigation and research, and of course, a new element entered into it, namely that of preventing the injury or death of the operator.

The great complexity of the problem induced Langley to seek the services of a mechanical engineer, and on the recommendation of Professor Thurston, Mr. Charles M. Manly was appointed, and proved to be a most efficient and faithful worker. It was hoped that the engine could be obtained and the frame-work of the new aerodrome completed by the early part of 1899, but this was not to be. The engine builder though he exerted himself to the utmost and, indeed, lost much money in his effort, was not able to produce an engine which would give anything like the desired h.p. within the allowable weight. Another series of disheartening failures and disasters followed. As a preliminary, an aerodrome one-quarter size of the proposed man-carrying one was constructed and trial flights made with success, but this small machine could not, of course, carry an operator. In addition to the problem of the construction of the large machine, a new apparatus for launching was devised and a new location, about forty miles below Washington on the Potomac was selected. It became necessary here to have a tug-boat and housing for the workmen, who could not come and go from Washington every day.

Nowadays, when aeroplanes are among familiar objects and almost everyone has seen them start and land, it seems that a serious mistake was made in the elaborate launching apparatus, and in the principle of launching over water, but it is easy to be wise after the event, and we must always keep in mind that Langley was working in a field in which there was no definite guidance, save his own studies and experiments.

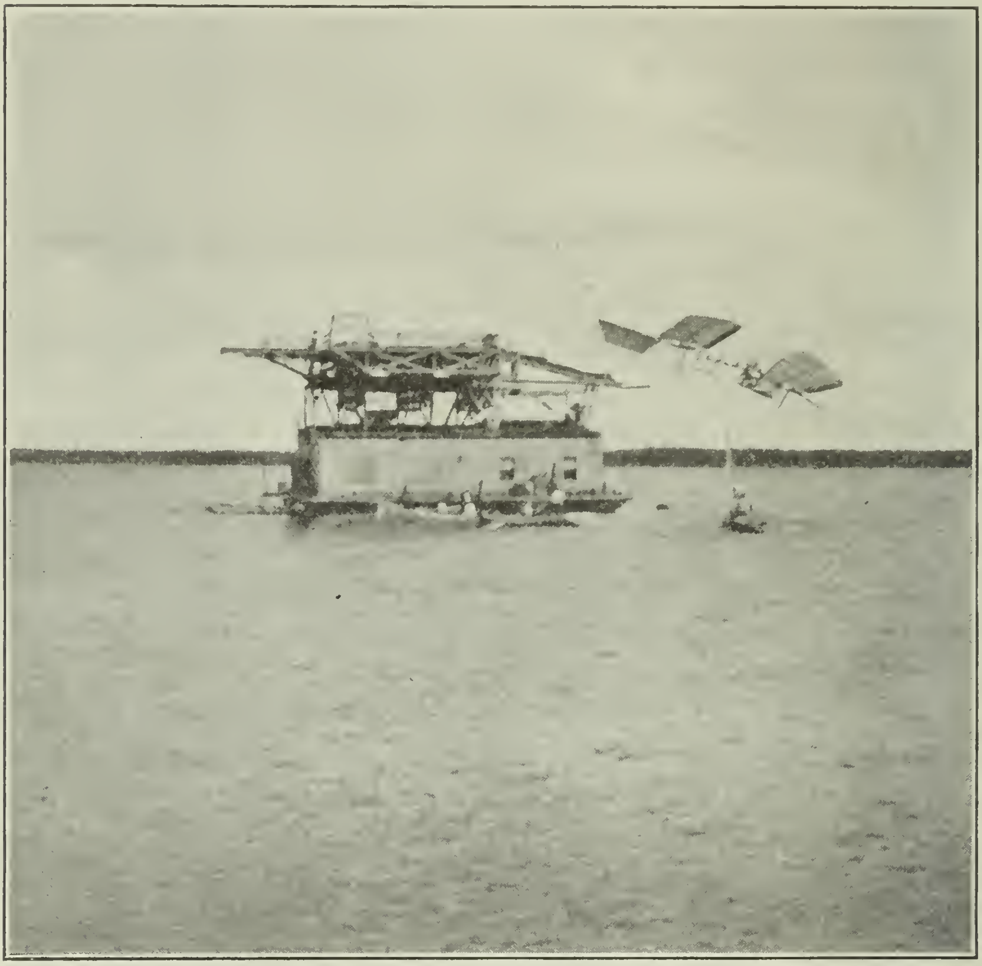
The engine-builder having finally given up the problem, efforts were made to get some European builder to manufacture the apparatus, Europe being, it was thought at that time, ahead of America in the application of the internal combustion motor. No one could be found willing to undertake the contract. Under these circumstances, Mr. Manly undertook the work. He obtained the parts of the engine which the American builder had made and in the latter part of 1900 began his work. He was able in September of that year, to construct an engine weighing 108 pounds which gave on the Prony brake, 18.5 h.p. at 750 r.p.m. The cylinders were, however, without water-jackets, being cooled with wet cloths, which of course would permit only short runs.

The details of the development of the engine, of the difficulties with sparking apparatus, carburetors, pistons, packing, lubrication and all the other vexations that go to make up what are collectively known as "engine troubles" are described vividly and fully in the "Memoir," but space does not permit of even a brief summary here. Not the least of the troubles in the history of the affair was the weather, which was very often exceedingly unfavorable.

Mr. Manly volunteered to be the operator for the first trip of the aerodrome. His chief consented to this, though with much reluctance. Every possible precaution was taken to prevent serious accident, and on October 7, 1903, about sixteen years after the work had begun at the Allegheny observatory, the machine was launched with Manly in the aviator's chair. It was a little after noon that the machine glided down the launching track. The operator soon felt the sensation of being free in the air, when he noted that he was plunging downward at a very sharp angle, and instinctively grasped the wheel which controlled the Pénaud tail, intending to throw it up so as to depress the rear, but the effort failed, the machine crashed into the water and it was with some difficulty that the operator was saved from drowning. The machine was recovered from the water and certain slight defects discovered as the cause of the mishap. Arrangements were made to remedy these and the party returned to Washington, after giving out a brief statement to the press. Fortunately, an excellent photograph had been secured just as the machine left the launching platform, and also another taken close to the wings, from which certain important facts can be easily established.

Examination showed that the machine was not seriously injured and it was decided to make another attempt, but for convenience a spot much nearer to Washington was chosen. On account of the lateness of the season, favorable weather was unusual, and it was December 8 before conditions were satisfactory. Some delay occurred in getting the machine taken to the place of trial, and darkness was setting in and the wind had become strong and gusty. Nevertheless, Manly took his station at the wheel, and the

FIG. 2.



Flight of large aerodrome, October 7, 1903. "Langley Memoir on Mechanical Flight." Plate 95.

machine was launched, but something happened that has never been clearly determined. The machine shot upward and then fell into the water, entangling the pilot, who again narrowly escaped drowning. Owing to the darkness the official photographer got no pictures, as his shutters were set to too high speed, but a representative of the *Washington Star* secured a small photograph, which on enlargement showed some points of importance, principally that the accident was due to the rudder becoming entangled in the launching track, owing to the breakage of some part of the mechanism by which it was connected to the main frame.

The situation became very distressing. The inventor felt that he could not ask for further funds from the Smithsonian Institution, and the Board of Ordnance and Fortification having been severely criticized on the floor of Congress for its original allotment for the work, it was deemed inexpedient to ask for further aid, as it might incur a curtailment of the funds placed at the disposal of the Board.

In 1904, Manly made efforts to secure assistance from wealthy Americans, but all whom he approached declined to aid unless arrangement would be made for later commercialization. Langley had years before tempting offers of this character, but had always declined and he again declined to accept these conditions. In 1907 he died. Had he been spared a few years he would have seen all his hopes realized as the sequel shows.

THE SEQUEL.[2]

May 6 is celebrated in Washington, informally, as Langley Day, being the anniversary of the first satisfactory flight of a heavier-than-air machine. In March, 1914, Glenn H. Curtiss, aviator and inventor, was invited to take part in the ceremonies on the next occasion. He replied: "I would like to put the Langley Aerodrome itself in the air." Secretary Walcott, of the Smithsonian Institution, at once granted the request, and in April the machine was taken to the Curtiss plant on Lake Keuka, Hammondsport, N. Y. It was overhauled but not materially changed, except to put hydroplane floats on it. On May 28, 1914, two months before the great war broke out, and eighteen years after the successful flight of the first aerodrome, the craft of 1903 was lifted into the water with Curtiss at the wheel, and many eager camera men waiting with loaded weapons. Pointed somewhat across the wind, the machine automatically headed into it, rose in level poise, soared steadily for 150 feet and landed softly in the water. After a few more flights, the engine and propellers were replaced by an 80 h.p. Curtiss motor, and direct-connected tractor propellers. In the absence of Mr. Curtiss, a pupil of his school, Mr. Doherty, took the wheel. Beginning Sept. 17, a number of flights were made, which demonstrated that the general principles of Langley's construction were perfectly sound, and to him must be given the credit of being the pioneer in practical aviation, and of having, by his devotion and persistence, helped to bring into a field of scientific inquiry what had been previously almost entirely in the possession of visionaries or charlatans. In this connection we must not overlook the services of Manly, to whom is due largely the construction of a satisfactory gasoline engine, then first used in an aeroplane, and who twice risked his life in trials of the large machine.

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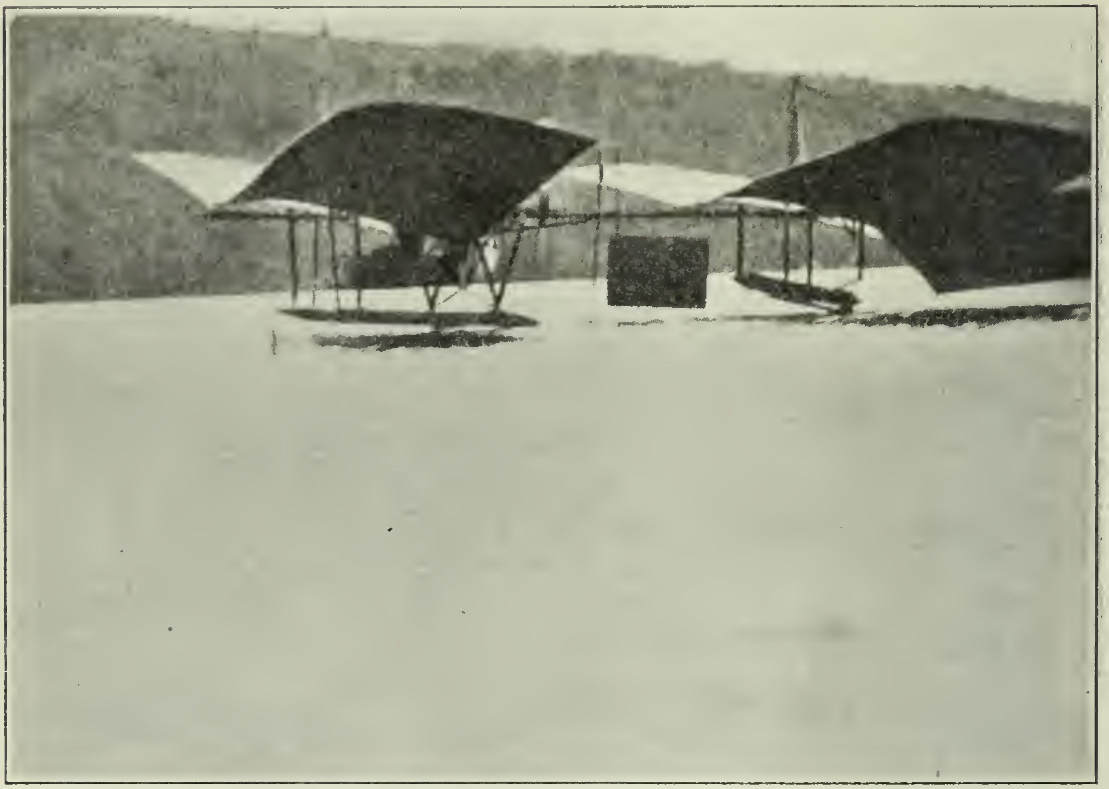
[2] For most of the data of this paragraph I am indebted to an article by Dr. A. F. Zahm, in *Ann. Rep. Smithson. Inst.* for 1914.

FIG 3.



Langley aerodrome rising from water, with Glenn H. Curtiss as pilot, June 2, 1914, Lake Keuka, N. Y. A. F. Zahm, Smithsonian Reports, 1914.

The following paragraphs are copied verbatim from the article indicated in the footnote on page 61:

"Dr. Langley's aerotechnic work may be briefly summarized as follows:

"1. His aerodynamic experiments, some published and some as yet unpublished, were complete enough to form a basis for practical pioneer aviation.

"2. He built and launched, in 1896, the first steam model aeroplane capable of prolonged free flight and possessing good inherent stability.

"3. He built the first internal-combustion motor suitable for a practical man-carrying aeroplane.

"4. He developed and successfully launched the first gasoline model aeroplane capable of sustained free flight.

"5. He developed and built the first man-carrying aeroplane capable of sustained free flight."

Gas Masks. E. C. PORTER. (*American Machinist,* vol. 49, No. 20, p. 911, November 14, 1918.)—German poison gas has been found harmless against gas masks worn by the United States troops in France. Field tests show that these masks afford twenty times more protection than German masks, and there is not a single case on record of an American soldier falling victim to a German gas attack when wearing the masks manufactured in the United States. This fact has been so thoroughly established by repeated experiences that military authorities place the blame for gas poisoning on the carelessness of the victim. Many American Army officers believe that in most cases the men who get gassed should be courtmartialed, not decorated. Every American soldier who goes to France is a gas-mask expert. He has been trained to adjust his "land life preserver" with almost incredible speed. The mask is put on with five motions of the arm and hands. Although a gas mask is a very uncomfortable article to wear the first few times, the soldier soon becomes accustomed to this handicap on the natural way of breathing. It fits over the head like a baseball catcher's mask. A nose clip closes the nostrils and insures breathing through the mouth by a tube connected with a canister filled with chemicals. The exhaled breath leaves through a flutter valve near the chin. Air cannot reach the mouth except by passing through the chemicals in the canister, and exhaustive experiments show that these chemicals never fail to extract the poison.

Better Frequency Control. H. E. WARREN. (*General Electric Review*, vol. 21, No. 11, p. 816, November, 1918.)—As is well known, the ordinary method of measuring frequency is by means of a meter which indicates upon a scale the value at any instant. Such a meter, under observation by a switchboard operator, serves to establish the speed of the turbines which is regulated through the electric speed controllers of the governors manipulated from the switchboard. This common method of regulation has certain faults which hitherto have not been emphasized because there has been no better way of accomplishing the regulation. An improved method of maintaining frequency, which has been in actual use during the past two years by a few of the largest power companies in New England and New York City, differs radically from the conventional plan. No frequency meter of the ordinary type is required. Instead, a device, which conveniently and accurately compares the integrated alterations with elapsed time, serves as a guide to the operator for adjusting the speed of the turbines. The device is comparatively insensitive to the instantaneous value of the frequency, but shows its average value with the very greatest precision.

The instrument itself, which is known as the Warren master clock, consists of a precise complete pendulum clock with two dials, placed one above the other. The lower one, which is of no particular importance for the purpose, serves merely to indicate the time in the conventional manner. The upper dial, of larger diameter, has a hand which revolves once in five minutes. Mounted upon the upper five-minute dial of this clock is an additional hand which is gold-colored to distinguish it from the black clock hand. This gold hand is wholly independent of the clock movement and is driven through gearing by a small self-starting synchronous motor. This motor is connected permanently through any convenient potential transformer to the alternating current system. The gear-ratio between the gold hand and the motor is such that at normal frequency, for example 60 cycles, the hand will revolve once in precisely five minutes. Incidentally the synchronous motor keeps the pendulum clock movement constantly wound at uniform tension.

After the clock has been started and regulated, the gold and black hands on the five-minute dial are set over each other, and the operators are instructed to adjust the speed control switches of the turbines occasionally, if they observe any tendency of the gold hand to gain or lose with respect to the black hand. The clock gives a true indication of the average value of the speed. It does not respond visibly to momentary fluctuations and serves, therefore, to establish a correct base line for the frequency.

A NEW THEORY OF PLATE SPRINGS.* †

BY

DAVID LANDAU and PERCY H. PARR.

Having completed our study of the reactions and deflections of springs with square pointed leaves, we pass on to the study of the

No. 2 or Trapezoidal (Trap') Leaf Point.

This type of point is shown on a larger scale in Fig. 18, on which are also given the symbols which will be used in the analysis. The end of the leaf is of uniform thickness with the central portion, but it is cut off to a straight taper in the plane of the width.

We shall use I_0 to indicate the moment of inertia of the untapered portion of the plate, for this and for all other types of tapered points.

In order to determine the deflections of leaves with the No. 2 point we have:

First: *From* $X = 0$ to $X = l - a$.

For this portion of the leaf the cross section is uniform, and equations (22) to (24a) for the No. 1 point apply directly.

Second: *From* $X = l - a$ *to* $X = l$.

For this portion of the leaf it is readily seen that the moment of inertia is:

$$I = I_0 \frac{l + b - x}{a + b}$$

and therefore:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} = -\frac{(a + b)(l - x)}{l + b - x} \qquad \text{(29)}$$

Integrating this equation, and determining the value of the constant of integration from the fact that the value of dy/dx

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* Communicated by the Authors.

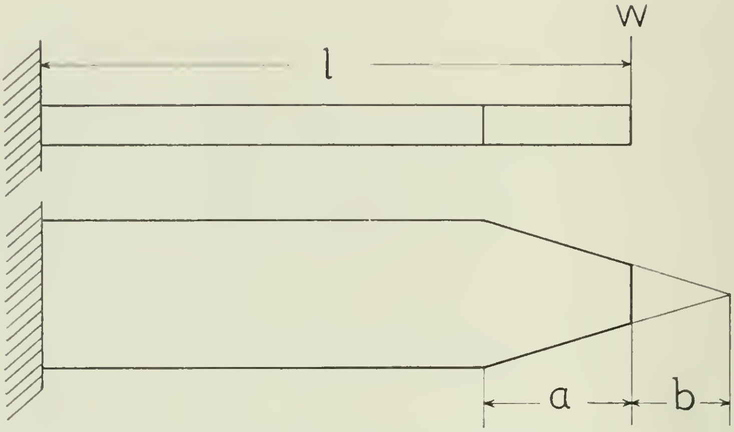
† Concluded from page 721, Vol. 186, December, 1918.

given by the integral for $x = l - a$ must be equal to that given by equation (23) for the same value of x, there results:

$$\frac{EI_0}{W}\frac{dy}{dx} = (a+b)x + (a+b)\,b\log\frac{l+b-x}{a+b} + (l-a-b)(l-a) - \frac{(l-a)^2}{2} \qquad \text{(30)}$$

Integrating again, and determining the value of the constant of integration from the fact that the value of y given by the integral for $x = l - a$ must be equal to that given by equation (24) for the same value of x, there results:

FIG. 18.



$$\frac{EI_0}{W}y = (a+b)\frac{x^2}{2} + \left\{\frac{(l-a)^2}{2} - b(l+b)\right\}x - (a+b)\,b\,(l+b-x)\log\frac{l+b-x}{a+b} + (a+b)\,b\,(l-a) + \frac{b\,(l-a)^2}{2} - \frac{(l-a)^3}{6} \qquad \text{(31)}$$

When using these equations it must be remembered that the logarithms are natural or hyperbolic ones, to the base e, and not the common logarithms to the base 10.

At the end of the leaf, where $x = l$, the above two equations reduce to:

$$\frac{EI_0}{W}\frac{dy}{dx} = \frac{l^2+a^2}{2} + ab + (a+b)\,b\log\frac{b}{a+b} \qquad \text{(30a)}$$

$$\frac{EI_0}{W}y = \frac{al^2}{2} - \frac{ab\,(a+2b)}{2} + \frac{(l-a)^2\,(2l+a)}{6} - (a+b)\,b^2\log\frac{b}{a+b} \qquad \text{(31a)}$$

These equations for point No. 2 are very much more complex than are the corresponding ones for point No. 1, but there is no real difficulty in applying them to any particular case—it being merely a matter of arithmetical work. For the sake of uniformity and in order that comparisons may be made, we now apply these equations to the spring shown in Fig. 19, which is the same as that of Fig. 17 except that the leaves have been given a No. 2 taper.

Plate No. 1.

We have $l = 4$, $a = 1.5$, and $b = 1$: and on inserting these values into equation (31a) there results:

$$\frac{EI_1}{W_1} y_1 = \frac{1.5 \times 4^2}{2} - \frac{1.5 \times 1\,(1.5 + 2 \times 1)}{2} + \frac{(4 - 1.5)^2(8 + 1.5)}{6}$$
$$- (1.5 + 1) \log_e \frac{1}{1.5 + 1}$$
$$= 21.5636$$

and since $EI_1 = 30772$ (see example of point No. 1 for I, etc.) we have $y_1 = .0007008\ W_1$, or

$$A_1 = .0007008.$$
$$A_2 = 0 \text{ as always.}$$

Plate No. 2.

The reaction W_1 is applied to the non-tapered portion of plate No. 2, so that A_3 and A_4 will be the same as in the example of the No. 1 point, that is:

$$A_3 = .0004366$$
$$A_4 = .0007641$$

For A_5 we have $l = 6$, $a = 1.5$ and $b = 1$ as before, and on inserting these values in equation (31a) it will be found that

$$y_5 = .001478\ W_2,$$

or

$$A_5 = .001478$$
$$A_6 = A_4 = .0007641$$

Plate No. 3.

For A_7 and A_8 the reaction W_2 acts at $l_2 = 6$, and from Fig. 19 it will be seen that in this case $a = .5$ and $b = 2$; inserting these values in equation (31a) it will be found that:

$$A_7 = .0009875$$

It will be noticed that the value of A_7 for this case is the same as that found in the previous one, and so it follows that A_8 will be the same as before: if not, then we should have to find the value of dy/dx for $x = l_2 = 6$, multiply this by $l_3 - l_2 = 7 - 6 = 1$ in this case, and add the result to A_7, in order to obtain A_8.

$$A_8 = .001234$$

For A_9 we have W_3 acting at the distance $l = 7$, $a = 1.5$ and $b = 1$, so that, on inserting into equation (31a) and reducing,

$$A_9 = .001571$$
$$A_{10} = A_8 = .001234$$

Making the other calculations, in the same manner as in the previous example, for the No. 1 point, it will be found that:

$$B_1 = .0007008$$
$$C_1 = .6718$$
$$B_2 = .0009647$$
$$C_2 = .6321$$
$$B_3 = .0007910$$
$$W_2 = 1.489\ W_1 = 436 \text{ lbs. for } W_1 = 293 \text{ lbs. as before:}$$
$$W_3 = 2.356\ W_1 = 690 \text{ lbs.}$$

also the maximum stress in plate No. 3 will be 106240 lbs. per sq. in. and the stiffness will be 1264 lbs. per inch deflection.

On comparing these results with those for the No. 1 point it will be found that the differences are negligible, so that we may state definitely that the No. 2 point, of proportions as generally found in practice, has no advantage whatever and that it is a waste of time and money to trim the points to this shape. The only advantage of the No. 2 point over the No. 1 is that of appearance—it pleases some people—but is really of no benefit as regards the endurance of the spring.

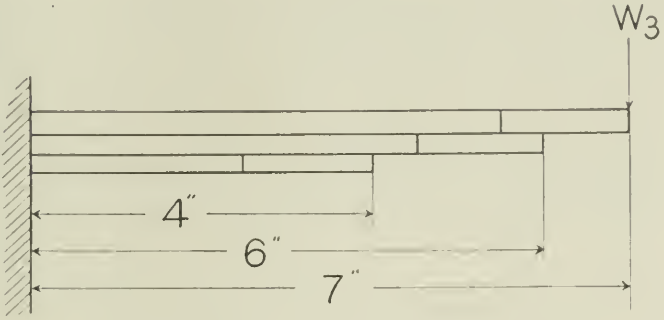
With an actual spring of course the master leaf must have a square point instead of the No. 2 point shown in Fig. 19; this simply means that the equations (22) to (24a) for the No. 1 point must be used when calculating the values of the A's for this leaf.

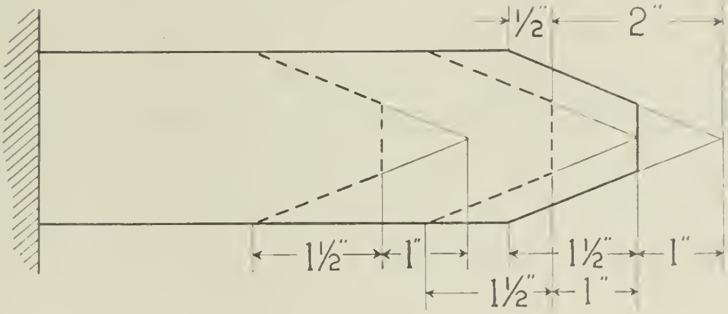
It seems opportune here to mention a point with regard to the particular equations to be used in certain cases, which, though not really difficult of comprehension, has nevertheless, been found to cause a certain amount of misunderstanding.

The trap point, or any other taper, may have any one of three forms: first, *the taper may be shorter than the overhang*; second, *the taper may be equal to the overhang;* and third, *the taper may be longer than the overhang.* These three cases are shown in Fig. 20, where they are marked *A*, *B*, and *C*, respectively.

For both the first and the second cases, when finding the *A*'s for the "plate above," referring to the reaction from the "plate below," it must be noticed that the reaction from the plate below is applied to the untapered portion of the plate above, and so the equations for the square-end plates (22) to (24a) must be used: it is well to observe that Case B is the limit of Case A. For the third case, where the tapers overlap, the equations for the No. 2 point must be used, that is, equations (29) to (31a).

Fig. 19.



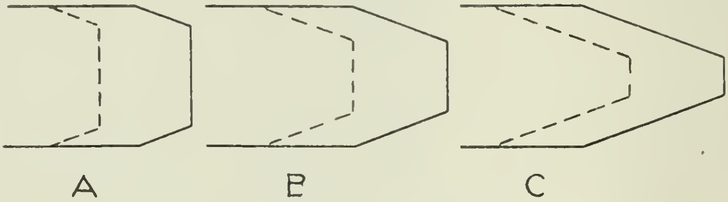


THE HISTORICAL PLATE SPRING—THE BASIC CASE OF THE OLD THEORY.

The historical case of plates of the same cross section, with equal steps, and linear tapers (tapers in width) ending in points at the end of the step as shown in Fig. 12, comes under this section, and although a spring of this kind is only of academic interest, still, considering the fact that practically all of the commonly accepted formulæ refer only to this special case, and also bearing in mind that it is of historical importance, it seems desirable to consider it from the viewpoint of the new theory, and, at the same time, to show that the new theory is in perfect agreement with the old one (formulated by the leading mathematicians of their day) for this special case. The new theory does not attempt in any way to overthrow the old one—in fact confirms it by showing its limitation—but the new theory shows that the old one is but a special case only, and one that never occurs in practice.

The new theory is so general in its scope as to cover actual practical conditions, and the relation of the new theory to the old one may be compared with that of Laurent's theorem to McLaurin's—the former is more general, and includes the latter.

Fig. 20.



In order to prove the statements regarding the equality of the reactions in the special case (Fig. 12) mentioned, a separate analysis appears to us to be the more direct way of proof. The fundamental condition is evidently that $\frac{M}{I}$ = constant, so that, for the tapered portion of the leaves:

$$\frac{EI_{n+1}}{W_{n+1}}\frac{d^2y}{dx^2} = l_{n+1}-l_n$$

Integrating this expression, and proceeding in the same manner as when obtaining equation (7), it will be found that the fundamental relation in this case is:

$$6E\delta_n = \frac{W_n(3l^3_n - 3l^2_n l_{n-1} + 3l_n l^2_{n-1} - l^3_{n-1}) + W_{n-1}(-3l_n l^2_{n-1} + l^3_{n-1})}{I_n}$$

$$= \frac{W_{n+1}(3l^2_n l_{n+1} - l^3_n) - 2W_n l^3_n}{I_{n+1}} \quad \dots\dots (32)$$

With plates of equal cross section $(I_{n+1} = I_n)$ and equal steps $(l_n = nl_1)$ the above equation reduces to:

$$W_n(4n^3 + 1) + W_{n-1}(-2n^3 + 3n^2 - 1) = W_{n+1}(2n^3 + 3n^2) \quad \dots\dots (33)$$

Putting $n = 1$ in this expression shows that $W_2 = W_1$: then putting $W_n = W_{n-1}$ shows that $W_{n+1} = W_n$, so it follows, from the inductive method of proof, that all of the W's are equal, and so as a consequence are all of the stresses.

For this special case, the deflection relation reduces to:

$$\delta_n = \frac{Wl^3_n}{2nEI} \qquad (34)$$

which shows that the deflection of a laminated spring of this type is 50 per cent. more than that of a plain plate with a moment of inertia equal to the sum of the moments of inertia of the plates forming the spring. This equation (34) is the ordinary formula of the academic texts.

There seems no further need to enlarge on this point; it is introduced simply on account of its historical importance, and in order to show that the new theory includes the old one as a special case.

FURTHER INVESTIGATION OF TAPERS.

We now pass on to the study of the other types of points:

No. 3 or Round Leaf Point.

It will readily be seen that the effect of this type of point on the stress and deflection relations of a spring is even less than that of the No. 2 point, and the same conclusions hold. All calculations for this type of point may be made by the equations given for the No. 1 point, with the assurance that they will be correct to at least four figures, which is ample for all practical purposes.

No. 4 or Circular Leaf Point.

The remarks made about the No. 3 point apply equally to this type. Exact calculations have been made for the No. 4 point, and they show that, for a leaf of which the length is double the width, the deflection at the end is almost exactly 1 in 1000 more than for a similar square-end leaf; this amount, which is already negligible for practical considerations, decreases directly as the cube of the length increases, so that the effect of this type of taper on an actual spring leaf is absolutely negligible.

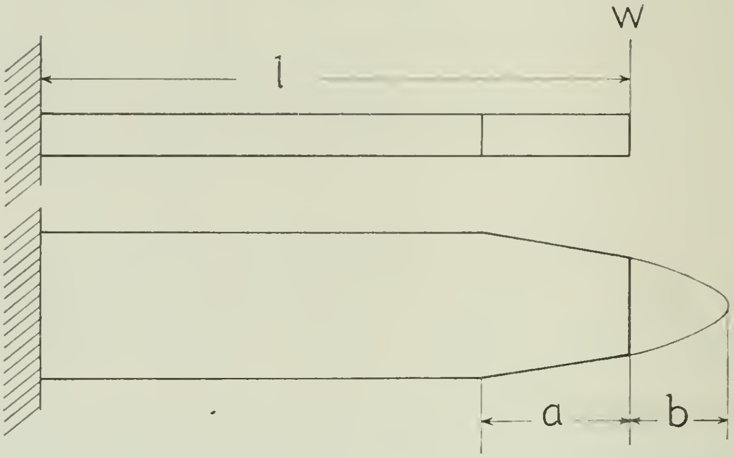
No. 5 or Parabolic Leaf Point.

This type of point is shown on a larger scale in Fig. 21, on which are also given the symbols which will be used in the analysis. The end of the leaf is of uniform thickness with the central portion, but it is cut to a parabolic form in the plane of the width. The effect of this taper is comparable with that of the No. 2 point, and is not usually of any importance.

In order to determine the deflections of leaves with the No. 5 point we have:

First: From $x = 0$ to $x = l - a$.

FIG. 21.



For this portion of the leaf the cross section is uniform, and equations (22) to (24a) for the No. 1 point apply directly.

Second: From $x = l - a$ to $x = l$.

For this portion of the leaf it is readily seen that the moment of inertia is:

$$I = I_0 \left(\frac{l + b - x}{a + b}\right)^{\frac{1}{2}}$$

and therefore:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} \quad \frac{(a + b)^{\frac{1}{2}}\ (l - x)}{(l + b - x)^{\frac{1}{2}}} \qquad \text{.......................................(35)}$$

$$\frac{EI_0}{W}\frac{dy}{dx} = (a + b)^{\frac{1}{2}} \left\{2b\,(l + b - x)^{\frac{1}{2}} - \frac{2}{3}(l + b - x)^{\frac{3}{2}}\right\} + C_1 \qquad \text{..................(36)}$$

$$\frac{EI_0}{W}\,y = (a + b)^{\frac{1}{2}}\left\{-\frac{4}{3}b\,(l + b - x)^{\frac{3}{2}} + \frac{4}{15}(l + b - x)^{\frac{5}{2}}\right\} + C_1 x + C_2 \qquad \text{..........(37)}$$

where:

$$C_1 = \frac{1}{2}(l-a)(l+a) + \frac{2}{3}(a+b)(a-2b) \quad \ldots\ldots (38)$$

$$C_2 = \frac{4}{15}(a+b)^2(4b-a) - \frac{1}{6}(l-a)^2(l+2a) - \frac{2}{3}(a+b)(a-2b)(l-a) \quad \ldots (39)$$

At the end of the leaf, where $x = l$, equations (36) and (37) reduce to:

$$\frac{EI_0}{W}\frac{dy}{dx} = \frac{4}{3}(a+b)^{\frac{1}{2}}b^{\frac{3}{2}} + C_1 \quad \ldots\ldots (36a)$$

$$\frac{EI_0}{W}y = -\frac{16}{15}(a+b)^{\frac{1}{2}}b^{\frac{5}{2}} + C_1 l + C_2 \quad \ldots\ldots (37a)$$

When $b = 0$ we have:

$$\frac{EI_0}{W}y = \frac{4}{15}a^{\frac{1}{2}}(l-x)^{\frac{5}{2}} + C_1 x + C_2 \quad \ldots\ldots (37b)$$

$$C_1 = \frac{1}{2}l^2 + \frac{1}{6}a^2 \quad \ldots\ldots (38a)$$

$$C_2 = \frac{1}{15}a^3 - \frac{1}{6}l(l+a)(l-a) \quad \ldots\ldots (39a)$$

and when $b = 0$ and $x = l$;

$$\frac{EI_0}{W}y = \frac{1}{3}l^3 + \frac{1}{15}a^3 \quad \ldots\ldots (37c)$$

As an example, if we apply equation (37c) to the bottom leaf of the spring of Fig. 17, making $a = 1.5''$ (the length used for the spring of Fig. 19) and $b = 0$, we find that $A_1 = .0007005$, as against .0006933 for the spring of Fig. 17 with the No. 1 point and .0007008 for the spring of Fig. 19 with the No. 2 point: in this case it is seen that the parabolic point makes even less difference than does the trap' point; in other cases the effect may be greater but it is never of any commercial importance.

The result of the foregoing analysis of *the effects of tapering the points of the leaves of leaf springs in the plane of the width only* may be said to be that *such tapering has no practical effect on the strengths, reactions, stresses, or flexibilities of the springs*—in fact, aside from the æsthetic point of view, such tapering is of no practical use and it is a waste of money to perform the operations incidental to their manufacture. The special "point trimming dies" are expensive to make and to keep in order, while the final result is simply that the springs *"look"* a little different from those with square pointed leaves.

We may here find the theoretical explanation of the observed practical fact that the heavy railroad and truck springs are usually made with square points, which are found to give just as good results in use as do those with sheared taper points.

With the advent of the reduction of costs of such modern appliances as the automobile came the demand, within the past three to four years, for reducing the costs of motor car springs.

As one of the costliest operations in spring manufacturing is the leaf tapering operation, some spring manufacturers at first decided to do away with tapering altogether. We have seen this practiced by at least one large automobile company—that is using a square end. Looks probably had much to do in discouraging the non-tapered springs, and as a substitute, and nearly equal in cost to the plain end, is the trapezoidal taper now found on many cars.

We have here an illustration in the use of "trap" points to make the eye believe that this is "as good" in results as the regular thickness tapering. The lack of analysis of these tapers has enabled the spring makers to dispose of an inferior product at a fair price with the assumption that the product was first class.

It is not our wish to have the reader infer that the spring maker really knew that trap' points were inferior to thickness tapers (indeed he cannot say what physical changes are produced by tapering) but we do wish to point out that springs of this kind are more economical to manufacture and they have not the "life" of the thickness tapered variety. We believe that this is the first time and place in which the illusion has been dispelled and the spring maker and spring user are herein given a clear answer to this question.[1]

We now proceed to the study of spring leaves which are tapered in the plane of the thickness, and the first case is that of the:

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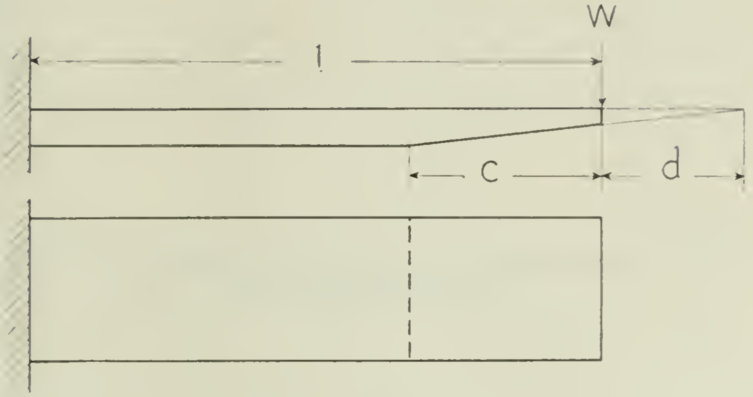
[1] The United States Government Liberty Truck Springs, Class B, are excellent illustrations of the inefficient use of material due to lack of this knowledge concerning tapers on the part of those who have "designed" these members.

No. 6 or Square-tapered Leaf Point.

This is the first case of tapering where the result is of real importance and has any considerable effect on the spring. The leaf is simply cut off square in the width, but it is tapered in the plane of the thickness. This point is shown on a larger scale in Fig. 22, on which are also given the symbols which will be used in the analysis.

In order to determine the deflections of leaves with the No. 6 point we have:

FIG. 22.



First, From $x=0$ to $x=l-c$.

For this portion of the leaf the cross section is uniform, and equations (22) to (24a) for the No. 1 point apply directly.

Second, From $x=l-c$ to $x=l$.

For this portion of the leaf it is readily seen that the moment of inertia is:

$$I = I_0 \frac{(l+d-x)^3}{(c+d)^3}$$

and therefore:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} = \frac{(c+d)^3(l-x)}{(l+d-x)^3} \qquad (40)$$

$$\frac{EI_0}{W}\frac{dy}{dx} = (c+d)^3\left\{\frac{-d}{2\,(l+d-x)^2} + \frac{1}{(l+d-x)}\right\} + C_1 \qquad (41)$$

$$\frac{EI_0}{W}y = (c+d)^3\left\{\frac{-d}{2\,(l+d-x)} - \log\,(l+d-x)\right\} + C_1x + C_2 \qquad (42)$$

where:

$$C_1 = \frac{1}{2}(l^2 - 3c^2 - 3cd - d^2) \quad \ldots\ldots (43)$$

$$C_2 = \frac{1}{6}\left\{ -l^3+3l(3c^2+3cd+d^2)-2c^2(4c+3d)+3d^2(c+d)+6(c+d)^3 \log(c+d) \right\} \ldots (44)$$

At the end of the leaf, where $x=l$, equations (41) and (42) reduce to:

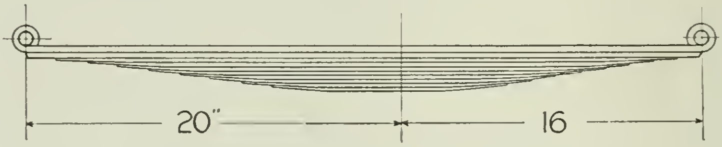
$$\frac{EI_0}{W}\frac{dy}{dx} = \frac{(c+d)^3}{2d} + C_1 \quad \ldots\ldots (41a)$$

$$\frac{EI}{W}y = (c+d)^3\left(-\frac{1}{2} - \log d\right) + C_1 l + C_2 \quad \ldots\ldots (42a)$$

The logarithms are of course natural or hyperbolic.

These equations (40) to (42a) may be said to be the most important of all in the theory of leaf springs. Unfortunately they are somewhat complex, but still there is no real difficulty in applying them to practical cases, as will be shown shortly. The work is admittedly tedious, but that is all, and the results are of such great importance that the mere labor of arithmetical computation becomes a minor consideration. For regular commercial work, tables can be—and have been—calculated which greatly reduce the work, and with the aid of these tables it does not take long (considering the value of the results) to work out completely any given spring.

FIG. 23.



It has already been shown that a taper in the width only has scarcely any effect on a spring. A taper in the thickness, on the other hand, has an enormous effect, as will shortly be shown by the application of the above equations for the No. 6 point. A combination of the two tapers—in the width and in the thickness—is sometimes of much importance, but in general the effect of the taper in the width is very much less than that of the taper in the thickness. The equations for the leaf point No. 6 may be said to be of fundamental importance as regards the application of the new theory of leaf springs to practical springs.

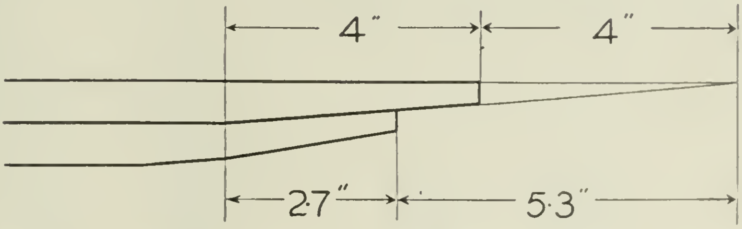
The No. 6 leaf point is of such great importance that we here give an example taken from practice instead of an academic case of a spring with only two or three leaves. This spring, which was used on one of the American automobiles, is shown in Fig. 23, and the details of the tapering are shown in Fig. 24. The details of the shorter (16″) end, so far as required for present purposes, are given in the following table:

Details of the Spring Shown in Fig. 23.

n	l_n	I_n	Z_n
1	5.6	.001215	.01197
2	6.9	.001215	.01197
3	8.2	.001215	.01197
4	9.5	.001215	.01197
5	10.8	.001215	.01197
6	12.1	.001215	.01197
7	13.4	.001557	.01415
8	14.7	.001982	.01665
9	16.0	.002566	.01982
10	16.0	.004013	.02675

Plate No. 9 (the long plate) is not tapered, and for the purpose of calculating the reactions, plates Nos. 9 and 10 must be taken together and considered as one plate, with a moment of inertia equal to the sum of the moments of inertia of each—that is $(.002566 + .004013) = .006579$.

FIG. 24.



It will be noticed that the overhangs, after the first, are all 1.3″ and that the tapers at the ends of the leaves are $c = d = 4''$ There are then only two cases to which we have to apply the taper equations: first, for the case where we are dealing with the reactions on the end of a leaf, when $c = d = 4$; and, second, when we are dealing with the reaction on a leaf from the "plate below," in which case the reaction acts at a distance of 1.3″ from the end of the leaf, so that we have $c = 2.7''$ and $d = 5.3''$, as is indicated in Fig. 24.

A study of equations (40) to (42a) will show that they may be considerably reduced for the numerical work in the following manner when the tapers are the same:

First, for $c = d = 4$.

On inserting these values of c and d into equations (43), (44) and (42a) there results:

$$C_1 = \frac{1}{2}(l^2 - 112)$$

$$C_2 = \frac{1}{6}(-l^3 + 336\,l + 5876)$$

for $x = l$,

$$\frac{EI}{W}\,y = -965.78 + C_1 l + C_2$$

Second, for $c = 2.7$, $d = 5.3$.

$$C_1 = \frac{1}{2}(l^2 - 92.89)$$

$$C_2 = \frac{1}{6}(-l^3 + 278.67\,l + 6672.9)$$

for $x = l$,

$$\frac{EI}{W}\frac{dy}{dx} = 48.302 + C_1$$

$$\frac{EI}{W}\,y = -1109.86 + C_1 l + C_2$$

Using these reduced expressions, the values of the various C's are readily calculated on inserting the various values of the l's; they will be found to be as follows:

	$c = d = 4$		$c = 2.7,\ d = 5.3$	
n	C_1	C_2	C_1	C_2
1	−40.320	1263.7	−30.765	1342.9
2	−32.195	1311.0	−22.640	1377.8
3	−22.380	1346.6	−12.825	1401.0
4	−10.875	1368.4	− 1.320	1410.4
5	2.320	1374.2	11.875	1403.7
6	17.205	1361.7	26.760	1378.7
7	33.780	1328.7	43.335	1333.3
8	52.045	1273.1		

Now using these values for the C's the various deflection relations may readily be calculated, giving the values of the A's, after which the B's and C's for the spring are to be found in the same manner as in the earlier example. It must, of course, be noted that the C's of equation (12) for the spring are not the C's of the above table; in the table the C's are the constants of integration as found from equations (43) and (44), while the C's for the spring are those found from equation (12). The use of the same symbol for denoting the two different things will not be found to cause any trouble in practice. The results of the calculations show that the various constants for the spring have the values given in the following table:

n	A_n	B_n	C_n	W_n
1	.00212	.00212	.631	1.000
2	.00000	.00207	.795	1.585
3	.00178	.00241	.869	1.993
4	.00245	.00288	.904	2.294
5	.00362	.00345	.930	2.537
6	.00245	.00410	.895	2.728
7	.00328	.00455	.871	3.049
8	.00426	.00481	.617	3.500
9	.00580	.00339		5.673
11	.00546			
12	.00682			
13	.00880			
15	.00846			
16	.01025			
17	.01271			
19	.01235			
20	.01465			
21	.01772			
23	.01360			
24	.01584			
25	.01871			
27	.01448			
28	.01662			
29	.01930			
31	.00575			
32	.00651			
33	.00741			

The values of A_{10}, A_{14}, etc., have not been given in the table, as they are respectively equal to A_8, A_{12}, etc., according to the theorem.

If we allow a stress of 100,000 lbs. per sq. in. in the bottom or short leaf, then the safe load on it will be $(100000 \times .01197)/5.6 = 214$ lbs. and the corresponding load on the short end of the spring, or W_9, will be $214 \times 5.673 = 1210$ lbs. The stiffness $= 1/B_9 = 1/.00339 = 295$ lbs. load per inch deflection. Allowing for the difference in the lengths of the two ends of the actual spring, this stiffness of the short end corresponds to a stiffness of 425 lbs. per inch for the entire spring.[2] All of the above figures have been calculated on the assumption that $E = 28 \times 10^6$, but a number of tests made some years ago showed that on an average E is slightly under 29×10^6, and adjusting the stiffness to this latter figure for E, it will be found that the calculated stiffness is 440 lbs. per inch. The average test of several hundreds of these springs showed that the stiffness was 447 lbs. per inch, so that the agreement is very good indeed, the difference being well under 2 per cent., while commercial springs of the same batch will at times vary five per cent., as a maximum. The agreement is, therefore, within the limits of manufacturing accuracy.

In order to complete the study of this spring, we must calculate the stresses in the various plates. The lower plates present no difficulty and for the top "compound plate" the load carried by each of the two plates is directly proportional to its moment of inertia, so that the thick plate No. 10 carries $1210 \times .004013/.006579 = 740$ lbs. and the thinner plate No. 9 carries the remainder, or 470 lbs. On performing the necessary calculations it will be found that the maximum stresses in the various plates at the centre point of encastrèment, are as follows:

Plate No.	*Stress.*
1	100000
2	95500
3	96600
4	97500
5	100000
6	100000
7	119000
8	106000
9	165000
10	192000

---

[2] For a complete study of the deflection of an excentrated spring the reader is referred to an article entitled, "The Partial and Total Deflections of Leaf Springs En Masse," in the *Horseless Age*, January 20, 1915; January 27, February 10, February 17, February 24, March 3, March 17, March 24, 1915, by David Landau and Asher Golden.

from which it will be seen that the greatest stress in this spring occurs in the top or master leaf. If the maximum stress in the spring is to be limited to 100,000 lbs. per sq. in. then the safe load on the short end will evidently be 1210 × 100000/192000 = 630 lbs., which will give the allowed stress in the master leaf, the stresses in the lower leaves being then all smaller; the total safe load on the spring on the same basis being 1133 lbs.

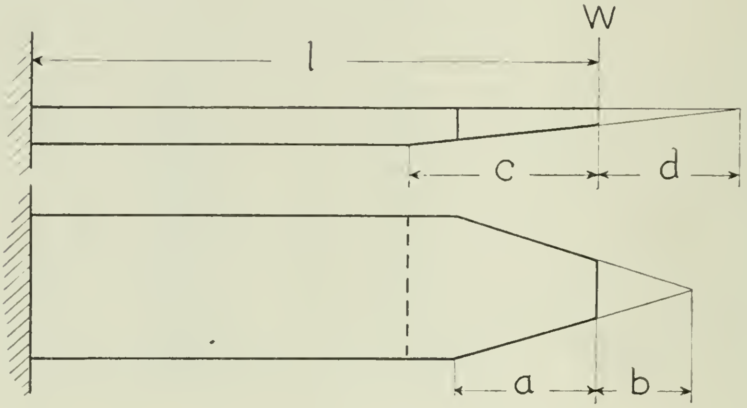
The taper which is now under consideration is so important that it appears to be advisable to work out this spring on the assumption that the leaves have square points (No. 1) in order to show the great difference made by the tapering. If this spring is worked out by the equations for the square point, it will be found that the reactions, etc., are as follows:

n	W_n	Stress
1	1.00	100000
2	1.49	83700
3	1.76	74100
4	1.93	69800
5	2.03	64100
6	2.11	64500
7	2.26	71900
8	2.48	79200
9	3.74	98800
10		114000

The total safe load on the short end of the spring with a stress of 100000 in the short leaf is 800 lbs. and with the same stress in the master leaf it is 700 lbs. while the stiffness of the short end is 321 lbs. per inch; this is a total spring stiffness of 479 lbs. per inch, and a total safe load of 1225 lbs.

A comparison of these figures with the corresponding ones for the tapered ends shows that the differences are very great; the final reaction in the case of the tapered spring has been increased by over fifty per cent., and the stress in the master leaf by nearly seventy per cent. With the trap', and other types of points which are tapered in the width only, the difference due to tapering has been shown to be in the neighborhood of only one per cent., so that they are of no practical value, but the above example shows that tapering in the thickness may produce relatively enormous effects and that almost any kind of stress distribution can be obtained by a suitable combination of tapering in the thickness and grading. It is not suggested that the particular example chosen for illustration is a good one; in fact, it will be seen that the safe load for the tapered spring in this particular case is slightly less than for the non-tapered one, though the tapered spring is the more flexible. This spring is an old design, produced sometime before the full effects of tapering were properly appreciated, with the consequence that the stresses in the upper part of the springs were somewhat excessive and in use the master leaves were generally the first to break. By properly adjusting the tapers, the stresses can be made very nearly equal throughout the spring, with a corresponding benefit, for in this case all of the metal is used to the greatest possible advantage. There are other modifying circumstances, which will be dealt with in our third paper, which tend to increase the stresses in the lower leaves and decrease them in the upper leaves, so that, ultimately, the stress distribution is better than would appear from the above figures for the tapered leaves and actually the tapered leaf spring is better than the untapered one, though the above figures tend to show the reverse.

FIG. 25.



We now pass on to the study of the leaves which are tapered in the plane of the width as well as in the plane of thickness.

No. 7 or Trapezoidal-tapered Leaf Point:

This type of point is shown on a larger scale in Fig. 25, which figure also shows the symbols which will be used in the analysis. The effects of the taper in the width are usually of secondary importance as compared with the effects of the taper in the thickness, but, nevertheless, there are cases where they are considerable.

In order to find the deflections of leaves with the No. 7 point we must note that there are several possible cases: for the present the two cases which have to be noticed are those for which $c>a$ and for which $c<a$. The first case, which is the most usual one, is shown in Fig. 25, and for this it will be noticed that from $x=0$ to $x=l-c$ the cross section of the plate is uniform, so that equations (22) to (24a) for the No. 1 point apply directly. From $x=l-c$ to $x=l-a$ the plate is of uniform width, but has a taper in the thickness, so that the equations for the No. 6 point must be used for this portion of the leaf. From $x=l-a$ to $x=l$ there is the double taper, for which taper we are now going to find the equations. For the second case, where $c<a$, it will easily be seen that for the portion of the leaf between $x=l-a$ and $x=l-c$ the thickness of the leaf is constant but the width is tapered, so that the equations for the No. 2 point are directly applicable to this portion of the leaf.

For the Double Taper of Fig. 25, from $x=l-a$ to $x=l$.

For this portion of the leaf, it is readily seen that:

$$I = I_0 \left(\frac{l+b-x}{a+b}\right)\left(\frac{l+d-x}{c+d}\right)$$

so that:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} = \left(\frac{a+b}{l+b-x}\right)\left(\frac{c+d}{l+d-x}\right)^3 (l-x) \quad \ldots\ldots\ldots\ldots\ldots\ldots (45)$$

In order to integrate this expression, it seems best first to put into the equivalent form:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} = (a+b)(c+d)^3 \left\{\frac{1}{l+b-x}\right\}\left\{\frac{-d}{(l+d-x)^3} + \frac{1}{(l+d-x)^2}\right\}$$

Then if we put:

$$z = \frac{l+b-x}{l+d-x}$$

we find that, so long as b is not equal to d:

$$x = l + d - \frac{d-b}{(1-z)}$$

and

$$dx = -\frac{d-b}{(1-z)^2}\,dz$$

also:

$$l+b-x = \frac{(d-b)z}{1-z} \text{ and } l+d-x = \frac{d-b}{1-z}$$

whence, after integrating:

$$\frac{EI_0}{W}\frac{dy}{dx} = \frac{(a+b)\,(c+d)^3}{(d-b)^3}\left\{\frac{dz^2}{2} - (d+b)\,z + b\log z\right\} + C_1 \qquad \text{(46)}$$

For the cases where the points of the leaves are tapered in both the width and in the thickness, the mathematical expressions for the constants (C's) of integration become so complex that it does not appear to be useful to give them; it seems to be better to evaluate them numerically when required. It is evident from considerations of continuity, that for the leaf point of Fig. 25, the value of dy/dx given by equation (46) for $x = l - a$, where the double taper commences, must be equal to the value of dy/dx given by equation (41) for the shorter portion of the leaf, for the same value of x. The procedure for finding C_1 is therefore to calculate the value of dy/dx for $x = l - a$ by means of equation (41) and then to insert this value in the left hand side of equation (46), which, combined with $x = l - a$ on the right-hand side, allows of the value of C_1 being calculated.

A second application of the substitution used for integrating equation (45) allows of integrating the integral equation (46), and, after absorbing the constant part of x into the constant of integration C_2, we obtain:

$$\frac{EI_0}{W}y = -\frac{(a+b)\,(c+d)^3}{(d-b)^2}\left\{d\left(z - \frac{1}{1-z}\right) + \frac{2b}{1-z}\,(z\log z - 1)\right\}$$
$$-\frac{d-b}{1-z}\times C_1 + C_2 \qquad \text{(47)}$$

C_2 must be found in the same manner as described for C_1, by equating the values of y from equations (42) and (47) for $x = l - a$. For the other cases, if $c = a$, it will readily be seen that the equations for point No. 1 must be used for comparison when determining the values of the C's and if $c < a$, then the equations for point No. 2 must be used, instead of those for the No. 6 point referred to in the preceding analysis.

We must now consider the *special case where* $b = d$, for which the preceding analysis fails to give the result. For this particular case we have:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} = (a+b)\,(c+d)^3\,\frac{(l-x)}{(l+b-x)^4} \qquad \text{(48)}$$

$$\frac{EI_0}{W}\frac{dy}{dx} = (a+b)\,(c+d)^3\left\{\frac{-b}{3\,(l+b-x)^3} + \frac{1}{2\,(l+b-x)^2}\right\} + C_1 \qquad \text{(49)}$$

$$\frac{EI_0}{W}y = (a+b)\,(c+d)^3\left\{\frac{-b}{6\,(l+b-x)^2} + \frac{1}{2\,(l+b-x)}\right\} + C_1x + C_2 \qquad \text{(50)}$$

This concludes our study of the No. 7 point, for which it does not appear to be necessary to give a numerical example, and we at once pass on to the consideration of the remaining types of double tapered leaf points.

No. 8 or Round-tapered Leaf Point.

The remarks made with reference to the No. 3 point apply also to this type of point—the effect of the rounding is absolutely negligible: the tapering in the thickness is very important, but the effect of the rounding is *nil,* so that the reactions, etc., for this type of point may for all practical purposes be calculated by means of the equations for point No. 6.

No. 9 or Circular-tapered Leaf Point.

The remarks made above regarding the No. 8 point apply, without modification, to this type of point. The rounding of the ends of the leaves with the No. 8 and No. 9 points may, perhaps, improve the appearance of the springs, but it has no effect on the strengths, flexibilities or endurances.

No. 10 or Parabolic-tapered Leaf Point.

This "double-tapered" type of leaf point is of more importance than the others, especially when combined with a "stress-equalizing slot," and is the subject of several patents in connection with plate springs.[3] The taper in the thickness has much more effect than has that in the width, but still, the effect of the taper in the width cannot be ignored. This point is shown on a larger scale in Fig. 26, where also are indicated the symbols

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[3] The reader may find it to his interest to peruse the patents which resulted from the research work contained in these papers. We direct attention to the following American patents, all issued in the name of David Landau:

Name of Patent	Date of Issue	Patent No.
Laminated Spring	Sept. 19, 1916	1,199,038
Laminated Spring	Sept. 19, 1916	1,199,013
Laminated Spring	Oct. 2, 1917	1,241,743
Spring	Oct. 2, 1917	1,241,744

Similar patents, in whole or in part, have been issued in Canada, France, Spain, Italy and England. Patents are also pending in Belgium, Russia, Canada and England. Applications were instituted in Germany prior to the war—at present these are withheld.

which will be used in the analysis. As with the point No. 7, there are several posssible cases according as to whether a is less than, equal to, or greater than c: these variations, however do not cause any trouble in application, since it is merely a matter of selecting from the equations given earlier in the paper those applying to the portion of the leaves before the double taper commences.

In order to determine the deflections of the leaves with the No. 10 point, we see on referring to Fig. 26, that from $x = l - a$, where the double taper commences:

$$I = I_0 \left(\frac{l + b - x}{a + b}\right)^{\frac{1}{2}} \left(\frac{l + d - x}{c + d}\right)^3$$

so that:

$$\frac{EI_0}{W}\frac{d^2y}{dx^2} = \left(\frac{a + b}{l + b - x}\right)^{\frac{1}{2}} \left(\frac{c + d}{l + d - x}\right)^3 \left(l - x \right) = (c + d)^3 \left(\frac{a + b}{l + b - x}\right)^{\frac{1}{2}}$$

$$\left(\frac{-d}{(l + d - x)^3} + \frac{1}{(l + d - x)^2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (51)$$

This expression is not an easy one to integrate, but so long as $b<d$, which is always the case in the practical spring, it may be integrated by means of the substitution:

$$l+b-x=(l+d-x)\sin^2\theta,$$

by the use of which we have:

$$-x=(d-b)\tan^2\theta-(l+b)$$

$$dx=-2\,(d-b)\tan\theta\sec^2\theta\,d\theta$$

$$l+b-x=(d-b)\tan^2\theta$$

$$l+d-x=(d-b)\sec^2\theta$$

$$\sin^2\theta = \frac{l+b-x}{l+d-x}$$

$$\cos^2\theta = \frac{d-b}{l+d-x}$$

$$\tan^2\theta = \frac{l+b-x}{d-b}$$

$$\sin\theta\cos\theta = \frac{(l+b-x)^{\frac{1}{2}}(d-b)^{1}}{l+d-x}$$

$$\frac{dx}{(l+b-x)^{\frac{1}{2}}(l+d-x)^3} = \frac{-2\cos^4\theta\,d\theta}{(d-b)^{\frac{5}{2}}}$$

$$\frac{dx}{(l+b-x)^{\frac{1}{2}}(l+d-x)^2} = \frac{-2\cos^2\theta\,d\theta}{(d-b)^{\frac{3}{2}}}$$

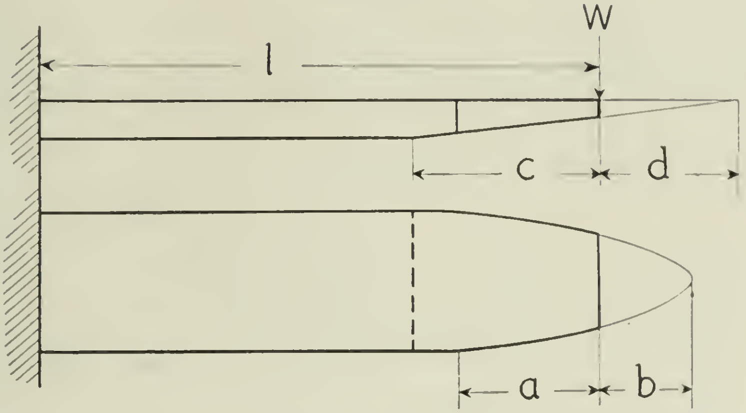
Using these relations, it will be found that:

$$\frac{EI_0}{W}\frac{dy}{dx} = \frac{(a+b)^{\frac{1}{2}}(c+d)^3}{4(d-b)^{\frac{3}{2}}}\Big\{(4b-d)(\sin\theta\cos\theta+\theta)+2d\sin\theta\cos^3\theta\Big\}+C_1. \quad (52)$$

where C_1 must be determined in the manner explained for the leaf point No. 7, by comparing the values of dy/dx from the equation corresponding to the first portion of the leaf with that given by the above equation.

A second application of the same transformation will enable equation (52) to be integrated in order to determine the value of y, and the result, after absorbing the constant part of x into C_2 will be found to be:

FIG. 26.



$$\frac{EI_0}{W}y = -\frac{(a+b)^{\frac{1}{2}}(c+d)^3}{4(d-b)^{\frac{3}{2}}}\Big\{(4b-d)(\theta\tan^2\theta+\tan\theta-\theta)+$$

$$2d(\theta-\sin\theta\times\cos\theta)\Big\}-C_1(d-b)\tan^2\theta+C_2 \ldots\ldots (53)$$

where, of course, C_2 is to be determined in a similar manner as before.

When using equations (52) and (53), it must be noticed that θ, when standing alone or appearing as a factor, must be expressed in circular measure or radians, since it has made its appearance on account of integrations of circular functions. The value is easily obtained by extracting the square root of $\sin^2\theta$ in order to obtain $\sin\theta$; referring to the ordinary tables of natural sines for the value of θ in degrees, minutes and seconds, and then referring to the table of Circular Measure, given in most books of mathematical tables, one may find the circular measure of the angle.

At the end of the leaf, where $x=l$, the expressions given for the values of the circular trigonometrical functions of θ reduce to:

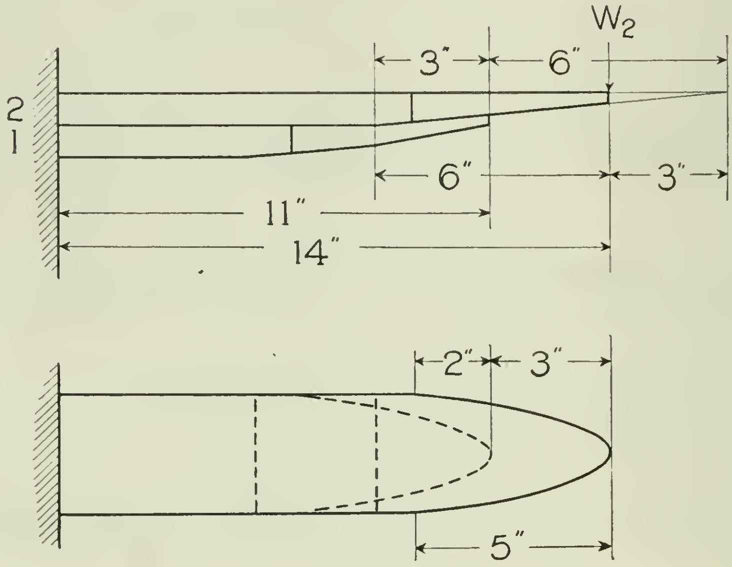
$$\sin^2\theta = b/d$$
$$\cos^2\theta = (d-b)/d$$
$$\tan^2\theta = b/(d-b)$$
$$\sin\theta\cos\theta = b^{\frac{1}{2}}(d-b)^{\frac{1}{2}}/d$$

and when we have $b=0$, then at the end of the leaf, with $x=l$, the $\theta=0$ (zero) and equation (53) reduces to the simple form:

$$\frac{EI_0}{W}y=C_2 \qquad \text{(53a)}$$

These expressions are admittedly very complex; in most cases, however, the somewhat simpler equations for the No. 6 point will be found to be sufficient to give the required degrees of accuracy, although there are occasions when it is necessary to apply the equations of the present section of this paper. There is no real difficulty in the application, but there is a *very considerable amount* of arithmetical labor; it seems impossible to avoid this, when dealing with these types of "double-taper" points, and so one must be satisfied to perform the laborious numerical work in order to obtain the very important results which may be deduced from their applications.

FIG. 27.



This type of point (No. 10) being of practical as well as theoretical importance, a numerical example will be given, although, on account of the very considerable amount of labor involved in working out completely an actual spring, the work here will be confined to two plates only. The two-plate spring for which the calculations will be given here is that shown in Fig. 27; on this figure most of the data necessary for the present purpose will be found. We now proceed to the necessary calculations.

First, for Plate No. 1.

Referring to Fig. 27, it will be seen that the double taper commences at $x=6$, at which point, on the left-hand side, the equations for point No. 6 hold. It will also be seen that $l_1=11$, $a=5$, $b=0$, $c=6$ and $d=3$.

Now using the equations for the No. 6 type of point for the point $x=6$ we find that:

$$\text{equation (43) gives } C_1=-25$$

$$\text{equation (44) gives } C_2=1965$$

then using these values:

$$\text{equation (41) gives } \frac{EI_0}{W}\frac{dy}{dx}=49$$

$$\text{equation (42) gives } \frac{EI_0}{W}y=162$$

Next inserting the values for *a, b*, etc., into the substitution equations for the No. 10 point, it will be found that:

$$\sin^2\theta=.625$$

$$\cos^2\theta=.375$$

$$\tan^2\theta=1.667 \text{ and } \tan\theta=1.291$$

$$\sin\theta\cos\theta=.484$$

$$\sin\theta = .79057 \text{ so that } \theta = 52^\circ\ 14' = .912 \text{ radians.}$$

We are now in position to determine the values of the constants C_1 and C_2 for the equations for point No. 10, and on referring to equations (50) and (51) it will be seen that we need the values of $\frac{(a+b)^{\frac{1}{2}}(c+d)^3}{4(d-b)^{\frac{5}{2}}}$ and $\frac{(a+b)^{\frac{1}{2}}(c+d)^3}{4(d-b)^{\frac{3}{2}}}$ which will be found to be 26.14 and 78.41 respectively.

Now referring to equation (52) and using the above values, we have:

$$49 = 26.14 \left\{ (4 \times 0 - 3)(.484 + .912) + 2 \times 3 \times .484 \times .375 \right\} + C_1$$

from which:

$$C_2 = 130$$

Next referring to equation (53) and using the above values, we have:

$$162 = -78.41 \left\{ (4 \times 0 - 3)(.912 \times 1.667 + 1.291 - .912) + 2 \times 3 (.912 - .484) \right\} - 130 \times 3 \times 1.667 + C_2$$

from which:

$$C_2 = 567$$

Having now determined the values of the C_1 and C_2 for use in equations (52) and (53) for the short (No. 1) plate, we need, for present purposes, simply to use equation (51a) and note that:

$$y_1 = \frac{567\, W_1}{EI_0}$$

For many cases, especially when the plates are of the same section, as is assumed to be the case in this example, it is convenient to discard the constant factor $1/EI_0$ in the intermediate operations and we may write:

$$y_1 = 567\, W_1 \text{ or } A_1 = 567$$

The discarded factor can be reintroduced at any time when found necessary and, in general, it will be found conducive to accuracy to omit it until it is required for final calculation. Of course, in any case where the cross section of the plate above is different from that of the plate below, it is necessary to introduce either the actual values of the factor or else the ratios of the two I's, the handling of which ratio will often be found to be the best method of procedure in practice, reserving the introduction of the value of E and I_0 until the final deflection relation is required.

We may here note that if there were no taper on this plate, so that it had the (No. 1) square point, the corresponding value of the deflection coefficient would be $11^3/3 = 443$, so that the taper has the effect of adding nearly 30 per cent. to the flexibility in this case.

The calculations for this example have been worked out mostly on a 10″ slide rule, so that it is possible—and even likely—that there are small errors, but these will not be sufficient to affect the general accuracy of the comparisons. For actual work in the spring designing room, where greater accuracy is desired, it is better to work out the results to not less than four, and preferably to five figures by the aid of a calculating machine; for present needs this did not seem to us to be necessary as the results are rather intended to indicate methods and offer general comparisons than to give examples of actual designs.

We now pass on to the calculations for the second plate.

Second, for Plate No. 2 and for the Reaction W_1 Acting at the Distance $l_1 = 11''$.

On referring to Fig. 27 it will be seen that for this section of the calculations, we have $l_1 = 11$, $a = 2$, $b = 3$, $c = 3$ and $d = 6$, while the double taper commences at $x = 9$.

Making use of the above values, we find that:

equation (43) gives $C_1 = 2$, and

equation (44) gives $C_2 = 2095$

then for the point $x = 9$, where the double taper commences,

equation (41) gives $\frac{EI}{W}\frac{dy}{dx} = 59$, and

equation (42) gives $\frac{EI}{W}y = 324$.

It will easily be seen that the angular functions are the same in this as in the first section of the calculations, and the application of equation (52) and the above figures show that the value of C_1 to be used in equations (52) and (53) is -217. Similarly, it will be found that the value of C_2 to be used in equation (53) is 535.

Having now found the values of the two constants C_1 and C_2 of integration for equations (52) and (53), we are in a position to calculate the values of dy/dx and y for plate No. 2 at the point $x = l_1 = 11$.

Using the reduced expressions for the angular functions, it will be found that:

$$\sin^2\theta = \cos^2\theta = \sin\theta\cos\theta = .500$$

$$\tan^2\theta = \tan\theta = 1$$

$$\theta = 45^\circ = .785 \text{ radians.}$$

Making use of these values, equation (52) shows that for $x = 11$ $dy/dx = 63W_1$, omitting the factor $1/EI$ as mentioned before, and equation (53) shows that $y_1 = 447W_1$.

The deflection at the end of plate No. 2, due to the reaction W_1 acting at the distance l_1 is, evidently, making use of the above figures, equal to $(447 + 63 \times 3)$ $W_1 = 636W_1$.

Third, for Plate No. 2 and for the Load W_2 acting at the Distance $l_2 = 14''$.

For this section of the calculations it will be seen that $l_2 = 14$, $a = 5$, $b = 0$, $c = 6$, $d = 3$ and the double taper commences at $x = 9$. Using these values we find that:

equation (43) gives $C_1 = 10.5$
equation (44) gives $C_2 = 1986$

then for the point $x = 9$, where the double taper commences,

$$\text{equation (41) gives } \frac{EI}{W}\frac{dy}{dx} = 84, \text{ and}$$

$$\text{equation (42) gives } \frac{EI}{W} y = 447$$

The circular functions are the same as for the first section of the calculations, so that,

equation (52) gives $C_1 = 165$ and equation (53) then gives $C_2 = 1007$.

An examination of the foregoing figures will show that:

$$A_1 = 567;\ A_2 = 0;\ A_3 = 447;\ A_4 = 636;\ A_5 = 1007;\ A_6 = 636,$$

it being of course understood that the factor $1/EI$ has been omitted.

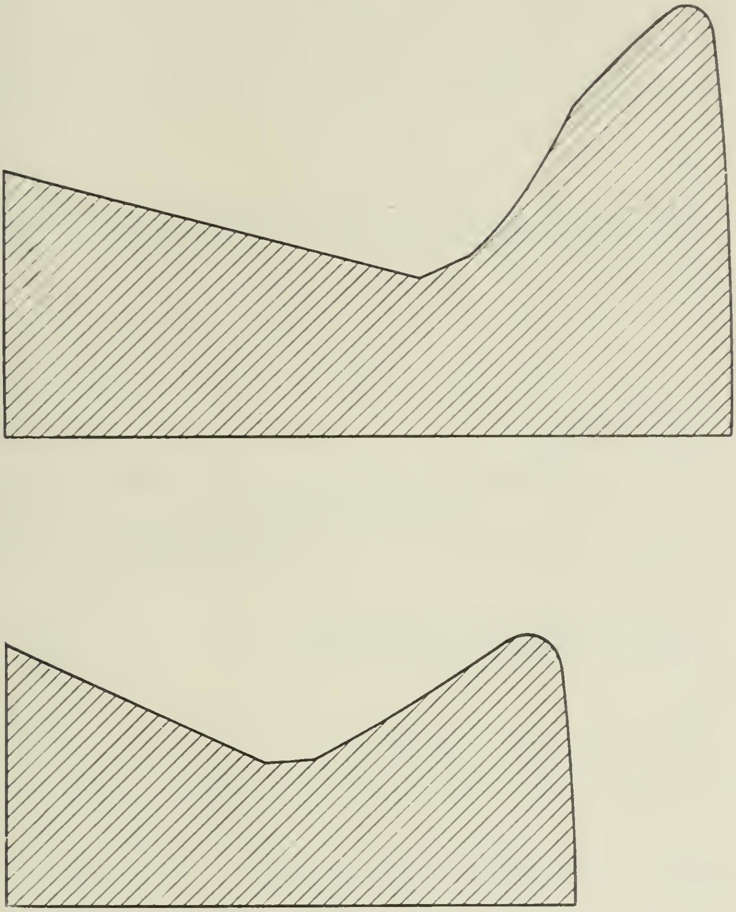
Now proceeding in the same manner as for the previous examples, we find that $B_1 = A_1 = 567$, $C_1 = .6282$, $B_2 = 607$, and for $W_1 = 1.000$ we have $W_2 = 1/.6282 = 1.592$.

Let us now suppose that the plates of the spring are 3″ wide and 3/8″ thick, with $I = .01318$ and $Z = .07032$, and allow a maximum stress in the bottom or No. 1 plate of 100,000 lbs. per sq. in. We will take E as equal to $28 \times 10.^6$

For this stiffness of the spring, we have $EI/B_2 = 28 \times 10^6 \times .01318/607 = 610$ lbs. load per inch deflection. The safe load on the bottom plate will be $100000 \times .07032/11 = 639$ lbs. and the corresponding load at the end of plate No. 2 will be $639 \times 1.592 = 1017$ lbs.

It is now easy to calculate the stresses in every part of each leaf of the spring; this has been done, and the results are as shown in Fig. 28. It will be seen that the maximum stress in the tapered portion of plate No. 1 is almost exactly the same as the maximum stress at the central point of encastrèment, being, in fact, 103,000 against 100,000 lbs. per sq. in. For the longer or No. 2 plate it will be noticed that the maximum stress in the tapered portion is considerably greater, being 164,000 lbs. per sq. in., which of course is considerably too high. This indicates that the taper of the No. 2 plate is too fine and that the point should be made somewhat different in design, which should be of such proportions as to bring the stress in the tapered portion down to about the same value as that in the body of the plate. The stress at the central point of encastrèment is just about the same as for the No. 1 plate, being 102,000 lbs. per sq. in., so that, except for the somewhat fine taper at the end of the No. 2 plate,

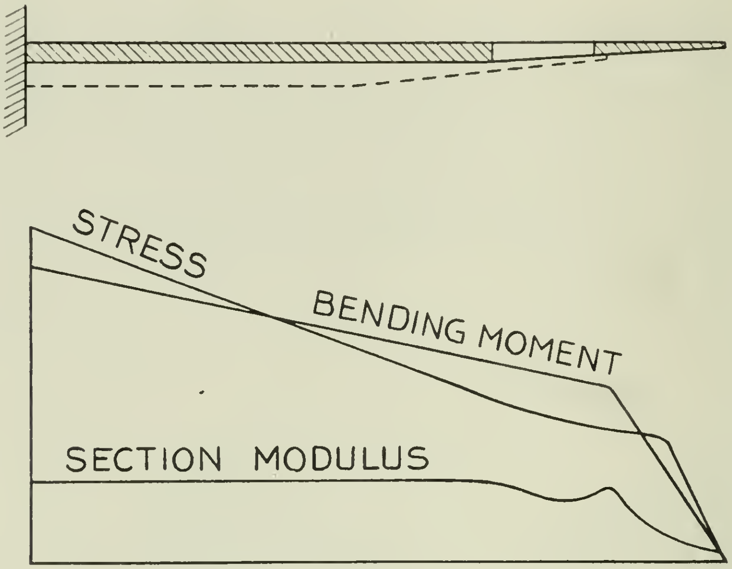
FIG. 28.



this two-plate spring may then indeed be said to be of economical proportions with fairly uniform stresses all over.

An examination of Fig. 28 shows that near the ending of the uniform section of the plates and at the commencement of the tapers, the stresses are considerably lower than either in the body of the plates or in the tapered portions. This shows that it would be an advantage to remove some of the metal in these portions of the plates—for it is always better to keep the stresses everywhere as uniform as possible, so as to utilize the metal to the greatest possible advantage—and it has been found that by punching suitably shaped and properly placed holes in the position mentioned, the stresses are equalized to a great extent and the endurance of springs is increased: this has been thoroughly verified by many tests on the endurance machine and also by regular use of such springs on the road. These holes or slots are termed "stress equalizing slots" and form part of U. S. Patent No. 13,199,013, September 19, 1916. The effect is shown in diagrammatic form in Fig. 29, which figure is copied from that of the patent specifications.

Fig. 29.



As has already been stated, in most actual springs the plates separate on the application of the load, except at the ends and at the centre point of encastrèment. This may be verified by calculating the deflection of the plates at intermediate points by the use of the proper equations and noting the differences of such deflections, of any two consecutive plates. The actual amount of separation is very small, to be sure, so that very accurate calculations are necessary in order to obtain concordant results.

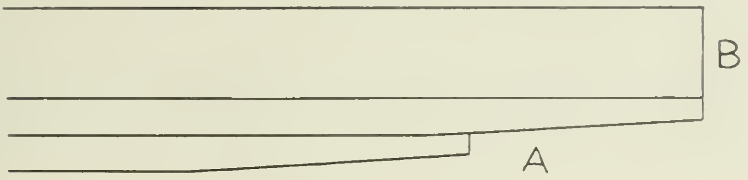
With the very flexible tapers which are sometimes used on the ends of the leaves, cases occur where the leaves tend to foul into one another. The effect of this is that instead of the leaves touching at the ends only, they have a contact for a distance depending on the flexibility of the tapered end. The only way to determine this is to calculate the deflections of the leaves at several points and compare the results. When this fouling tends to occur it shows that the tapers are too fine and instead of the reactions being at the tips of the leaves, they shift nearer to the centre of the spring, so that too fine a taper is equivalent to shortening the leaf. The calculations involving such "fine" tapers are complex, and seldom of commercial importance.

This completes the study of the reactions and stresses in the bodies of plate springs and there now remains only one more thing to be considered, in this paper, and that is the:

SEPARATION OF LOADS IN THE TOP COMPOUND PLATE.

It has previously been mentioned that when the "full length" plates are not tapered at all, they may, for primary purposes, be considered as equivalent to a single plate with a moment of inertia equal to the sum of the moments of inertia of the separate plates; then, after the final reaction has been found, it is evident that the various plates making the compound top plate will each support a portion of the load in direct proportion to its own moment of inertia. In this case, after finding the final load on the end of the spring, it is only necessary to divide this load in the ratios of the moments of inertia of the plates of the compound top plate, and the loads on the separate plates are at once determined. An example of this was given in our illustration for the No. 6 point.

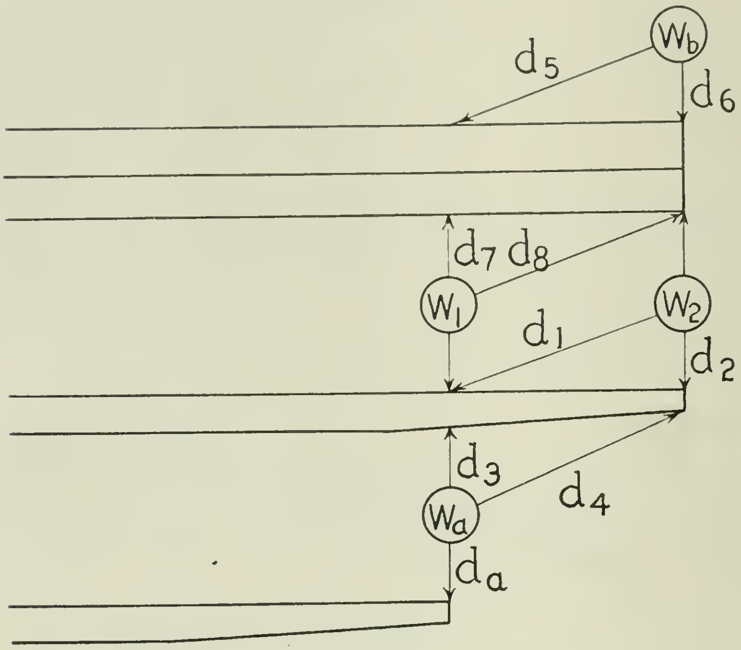
FIG. 30.



In actual springs it will be found, however, that the lowest of the long plates is generally tapered, and in this case a special investigation is necessary in order to separate the loads on the various plates, which have the same length.

The full length plates, including the main plate, which are not tapered, may be, for the primary calculation, considered as one plate with a moment of inertia equal to the sum of the moments of inertia of these plates, and the total load may afterwards be divided between them in the direct ratio of their moments of inertia, in the same manner as before. We may therefore consider the compound top plate to be made up of one tapered and one plain end plate, as shown in Fig. 30.

FIG. 31.



The various deflection coefficients which will be required in the analysis are shown in Figs. 30 and 31, in which it is to be understood that for the tapered plate:

W_2 produces a deflection d_1 at A and d_2 at B

$W_a - W_1$ produces a deflection d_3 at A and d_4 at B;

for the plain plate or plates:

$W_b - W_2$ produces a deflection d_5 at A and d_6 at B

W_1 produces a deflection d_7 at A and d_8 at B

and for the spring W_b produces a deflection d_b at B.

A consideration of the deflections shows that:

$$d_1 - d_2 = d_a \text{ (which is known)}$$
$$d_2 - d_4 = d_b$$
$$d_3 - d_7 = d_a$$
$$d_6 - d_8 = d_b$$

Now let $d_1 = k_1 W_2$, $d_2 = k_2 W_2$, $d_3 = k_3(W_a - W_1)$, $d_4 = k_4 (W_a - W_1)$, $d_5 - k_5(W_b - W_2)$, $d_6 = k_6(W_b - W_2)$, $d_7 = k_7 W_1$, and $d_8 = k_8 W_1$: Then, inserting these values in the above equations and solving in the usual manner, it will be found that:

$$\frac{W_1}{W_2(k_1k_4k_5 - k_2k_3k_5) + d_a(k_1k_6 - k_2k_5)} = \frac{-W_2}{W_a(k_3k_6k_7 - k_4k_5k_8) + d_a(k_3k_6 + k_6k_7 - k_4k_5 - k_5k_8)}$$
$$= \frac{W_b}{W_a(k_1k_4k_7 + k_3k_5k_8 - k_2k_3k_7 - k_1k_6k_7) + d_a(k_4k_5 + k_5k_8 - k_2k_7 - k_6k_7)}$$
$$= \frac{-d_b}{W_a(k_1k_4k_5k_8 + k_2k_3k_6k_7 - k_1k_4k_6k_7 - k_2k_3k_5k_8) + d_a(k_2k_3k_6 + k_2k_6k_7 - k_1k_4k_6 - k_2k_5k_8)}$$
$$= \frac{1}{k_1k_4k_5 + k_1k_5k_8 - k_1k_6k_7 - k_2k_3k_5} \quad \dots\dots\dots\dots (54)$$

which determines W_1, W_2, W_b and d_b.

The k's for use in the above equation are to be calculated in exactly the same manner as the A's of the earlier illustrations; there is no real difficulty, but there *is* a great amount of arithmetical work. The substitution of numerical values into the expressions given above offers no new features of interest, and there does not appear to be any necessity to give an example.

This concludes the analysis of reactions and stresses in plate springs as actually manufactured; the third paper will consider the internal stresses due to the "nip" produced in manufacturing and also the effect of the variation of the stresses on the life of a spring.

Meso-thorium as a Substitute for Radium. Anon. (Circular U. S. Bureau of Mines, December, 1918.)—The increasing demand for radium for medical work, but more particularly for luminous paint, has made the question of possible radium substitutes of considerable importance. Radium luminous paint has been used in the war for a number of purposes, more particularly on the dials of instruments used on airplanes, so that these instruments can be read at night; for electric push buttons, door numbers and small images for shrines, etc. The paint is permanently luminous in the dark and contains from 0.1 to 0.25 milligrams radium element to one gram of zinc sulphide. A luminous watch face usually has from ten cents' to twenty cents' worth of radium on it.

An excellent substitute for radium for certain purposes is meso-thorium. This is a radio-active element found in monazite sand and other thorium minerals. When first extracted it is not in a satisfactory condition for luminous paint, but must be allowed to "ripen" for several months or even a year before it can be used. During this time the alpha radiation which is required for luminous paint becomes sufficiently strong. On the other hand, the beta and gamma radiation of meso-thorium grows rapidly and it can be used for medical purposes within a few days after preparation.

Radium has a long life, half of it decaying in approximately 1600 years. Meso-thorium, on the other hand, has a short life, 5 or 6 years being its useful life for luminous paint purposes. The price in the past has varied from 40 to 60 per cent. of that of radium, the comparison being on products of equal activity. For medical purposes, therefore, it cannot compete with radium as long as there is plenty of the latter; for luminous paint, to be used on objects which themselves have a short life, it is an excellent substitute for radium and will tend towards the saving of radium for medical purposes. It undoubtedly has been used during the war, especially by the Germans. Some of the first luminous watch dials in this country probably contained meso-thorium imported from Europe. Until recently no meso-thorium was recovered in the United States, although large quantities of monazite sand are annually treated for the manufacture of incandescent gas mantles. Such a condition has represented an important mineral waste.

Shortly after the United States entered the war the Bureau of Mines made a coöperative agreement with the Welsbach Company of Gloucester, N. J., for the study of methods of extraction and recovery of meso-thorium. The work was carried on at the Rocky Mountain station of the Bureau of Mines at Golden, Colo., under the direction of Dr. R. B. Moore, Superintendent of the station, Dr. Herman Schlundt being assigned to the detailed work on the problem. Successful methods of extraction and recovery have been worked out and connected up with the regular metallurgical processes of the Welsbach Company. Meso-thorium is now one of the regular products made by this company. The next largest producers of thorium salts in the country, about the same time became interested in the recovery of meso-thorium and worked out its own methods. Consequently at the present time meso-thorium is recovered from practically all the monazite sand treated in the United States.

The details of the work of the Bureau of Mines will be published later. A preliminary announcement was made by Dr. Moore in a paper given at the September meeting of the American Institute of Mining Engineers at Colorado Springs. Incorrect press reports of this announcement gave rise to some serious mis-statements of facts, hence this statement. The Bureau of Mines has never claimed the discovery of meso-thorium, as this element was first identified and described by Hahn in 1905.

THE RELATIVE MERITS OF CAST-IRON, WROUGHT-IRON AND STEEL PIPE FOR HOUSE DRAINAGE PURPOSES.*

BY

WM. PAUL GERHARD, D.Eng., C.E.
Consulting Engineer, New York City.

An investigation relating to the relative life, deterioration by corrosion, and other characteristics of pipe materials used in the main drainage, soil and vent system of buildings made during the past summer, should be of particular interest to sanitary engineers, progressive plumbers, health inspectors, superintendents and engineers of office buildings and to dealers in pipe materials.

I shall not go into the details of how the investigation was carried on, as these will appear at length elsewhere. But the actual findings and the conclusions reached therefrom are of much practical importance, and go far towards solving two, until now, mooted quesions, *viz.:*

(1) As to the superiority of cast-iron pipe and its caulked joint over welded pipe put together with screw joints.

(2) As to the comparative degree of corrosion of mild-steel and of genuine wrought-iron pipe.

My personal beliefs, derived from many years of practical experience, have long been:

(1) That screw-jointed drainage systems were better than cast-iron pipe systems, particularly for tall buildings.

(2) That genuine wrought-iron pipe was superior to steel pipe.

These opinions were unquestionably confirmed by the investigation.

Recent claims of cast-iron pipe manufacturers, however, that *both* steel and wrought iron were liable to considerable corrosion and quick decay, had rather startled me, so that I was glad of being offered an opportunity to investigate personally many of the assertions made.

The history of the development of house drainage systems is so well known to many readers of this paper that I shall not dwell upon it.

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* Communicated by the Author.

This investigation, made in New York City, took in the principal buildings on both sides of Broadway, from Bowling Green (down-town) to Forty-second Street. Buildings less than 6 stories in height were omitted; we also passed by those erected less than five years ago, because they were not sufficiently old to give information of value as to the corrosion of pipes, for instance the Woolworth, Equitable Life, Adams Express, American Express Building and a few others.

The total number of buildings examined was seventy-eight, and distributed by age they ranged as follows:

Number of buildings over 30 years old	13
Number of buildings from 25 to 30 years old	10
Number of buildings from 20 to 25 years old	17
Number of buildings from 15 to 20 years old	17
Number of buildings from 10 to 15 years old	15
Number of buildings less than 10 years old	6
	78

Classified by pipe materials used, the buildings ranged as follows:

Number of buildings having cast-iron pipe systems	28
Number of buildings having black wrought-iron systems	1
Number of buildings having galvanized wrought-iron pipe systems	14
Number of buildings having black steel pipe systems	0
Number of buildings having galvanized steel pipe systems	12
Number of buildings having mixed wrought-iron and steel systems	23
	78

We noted carefully the age of each building and pipe installation, the number of floors, the pipe material used, the number of vent pipes on the roof, the number of samples taken from the vents and their condition, also the condition of the cellar drains. The names of the architect and of the plumbing contractor were also ascertained in many cases.

Cast-iron pipe systems were found in the oldest buildings, but in the later buildings preference seems to have been given to the screw-jointed system, both steel and wrought iron.

The roof vent pipes were selected as the principal objects of the inspection and the tests, because they were almost the only parts of the house drainage system, the interior condition of which could be freely ascertained. Their condition and degree of corrosion, together with the age of the installation, gave important information regarding the life of the different pipe materials. Such actual service tests must be considered superior to so-called "accelerated" corrosion tests on small quantities of pipe.

Of the 1676 vents counted on the roofs of the seventy-eight buildings, one-third were cast iron and two-thirds were of welded screw-jointed pipe. Over five hundred samples of material from these vents were obtained for the chemical tests, which were made to determine whether the pipes were of steel or of wrought iron. These samples were all taken and subsequently analyzed under my personal direction, so that no doubt was left as to the correctness and accuracy of the tests.

Inasmuch as the conclusions reached are based chiefly—though not entirely—upon the tests made, it will be well to describe these fully. The question as to whether a pipe is of wrought iron or of steel is one against which engineers and plumbers frequently run, and it would be well if they kept themselves better informed, so as to know how to go about it to determine whether a pipe is of steel or of wrought iron. This knowledge, as will be seen, can readily be acquired, and should really form part of the "stock in trade" of every progressive plumber.

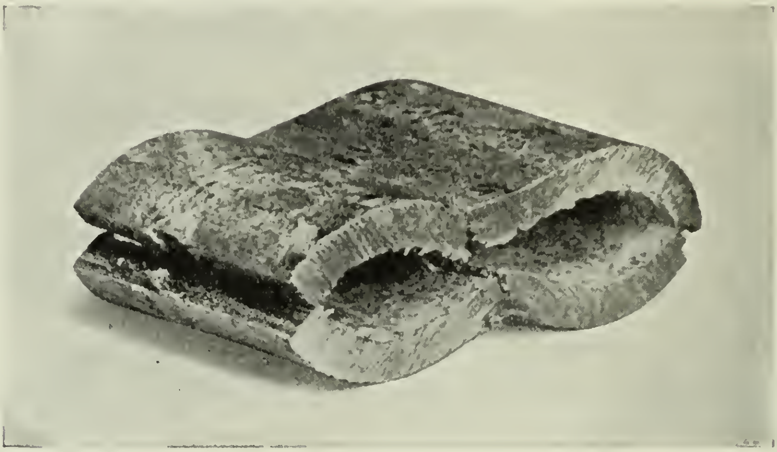
There are in use six principal tests, three of which are mechanical, two chemical and one microscopical. What test to use depends upon whether a large sample ring of a pipe can be obtained, or whether only chips or filings can be taken, as is the case when pipes are already installed and cannot be removed.

I. FRACTURE TEST.

If a piece of pipe is available, the crushing or fracture test can be made by any person; it is likewise the surest in its indications. Fig. 1 shows a piece of genuine wrought-iron pipe hammered flat to the point of fracture. The surface of the fracture appears ragged, dull gray and fibrous. Fig. 2 shows a piece of steel pipe, which after similar treatment presents an even, bright and crystalline fracture.

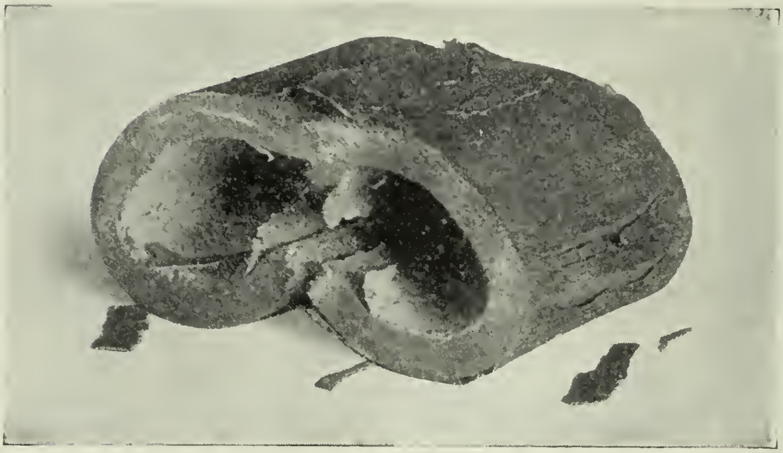
In connection with the fracture test it is interesting to note that when the pipe to be tested is galvanized, the galvanized coating does not scale or chip off if the pipe is wrought iron; it sticks to it and breaks with the iron without cracking (see Fig. 1). If, on the other hand, the pipe is of steel, the fracture test causes the galvanizing to peel off in scales or flakes, and this occurs almost at the first stroke of the hammer (see Fig. 2). These cuts, Figs. 1 and 2, are from a recent Bulletin, No. 41, May, 1918, of the A. M. Byers Co., in Pittsburgh.

Fig. 1.



Galvanized iron pipe.

Fig. 2.



Galvanized steel pipe.

II. THREADING TEST.

Another mechanical method of testing consists in cutting a thread on the pipe. A wrought-iron pipe, when being threaded, has the chips breaking and crumbling, whereas in a steel pipe the chip tends to curl and form a long spiral, which is apt to clog the die space during the threading.

III. CORROSION TEST.

This is in reality not a test, but merely the observation of the characteristic appearance of rusting. . It is, of course, restricted to pipes which have been in use for many years and which have begun to show the effects of corrosion. Speaking only from the observations made by me in the New York investigation, the fact became apparent that wrought-iron and steel pipes showed two very distinct forms of rusting. The wrought-iron pipes show "pitting" or became "pockmarked," while steel pipes "scale" and flake off.

Fig. 3 shows some black wrought-iron vent pipes, in use twenty-seven years, photographed on the roof of the Mail and Express Building, cor. Fulton and Broadway, while Fig. 4 shows steel vent pipes in use twenty-three years, photographed on the roof of the Townsend Building, No. 1123 Broadway. The different ways in which the two pipe materials corrode is quite apparent from the illustrations. Fig. 5 shows how cast-iron vent pipes corrode; they show a nearly uniform pitting, not unlike that of genuine wrought-iron pipes.

IV. THE ACID OR CHEMICAL TEST.

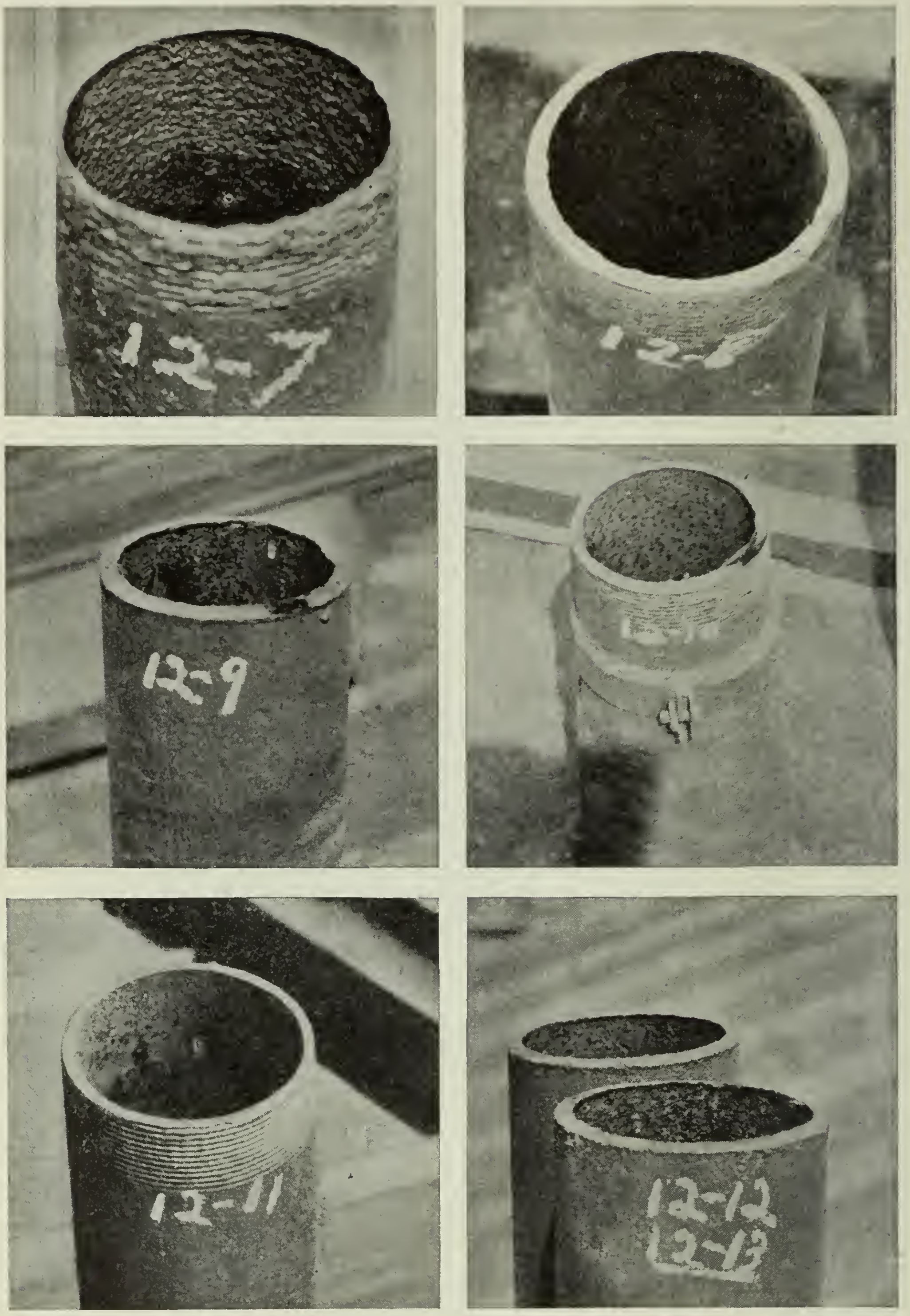
(See *Iron Age,* Dec. 23, 1909.)

To distinguish between wrought iron and soft steel the sample of pipe is cleaned from grease and scale and then immersed in a solution of 9 parts of water, 3 parts of sulphuric acid and 1 part of muriatic acid. The acids are poured into the water, and the mixture is allowed to cool. The pipe material to be tested is allowed to remain in the solution from fifteen to twenty minutes. It is then taken out and rinsed in clear water. The characteristic fibres of wrought iron will now show plainly, but if they should not do so the process is continued longer. Soft steel dissolves uniformly and without the fibrous structure found in wrought iron.

V. THE MANGANESE TEST.

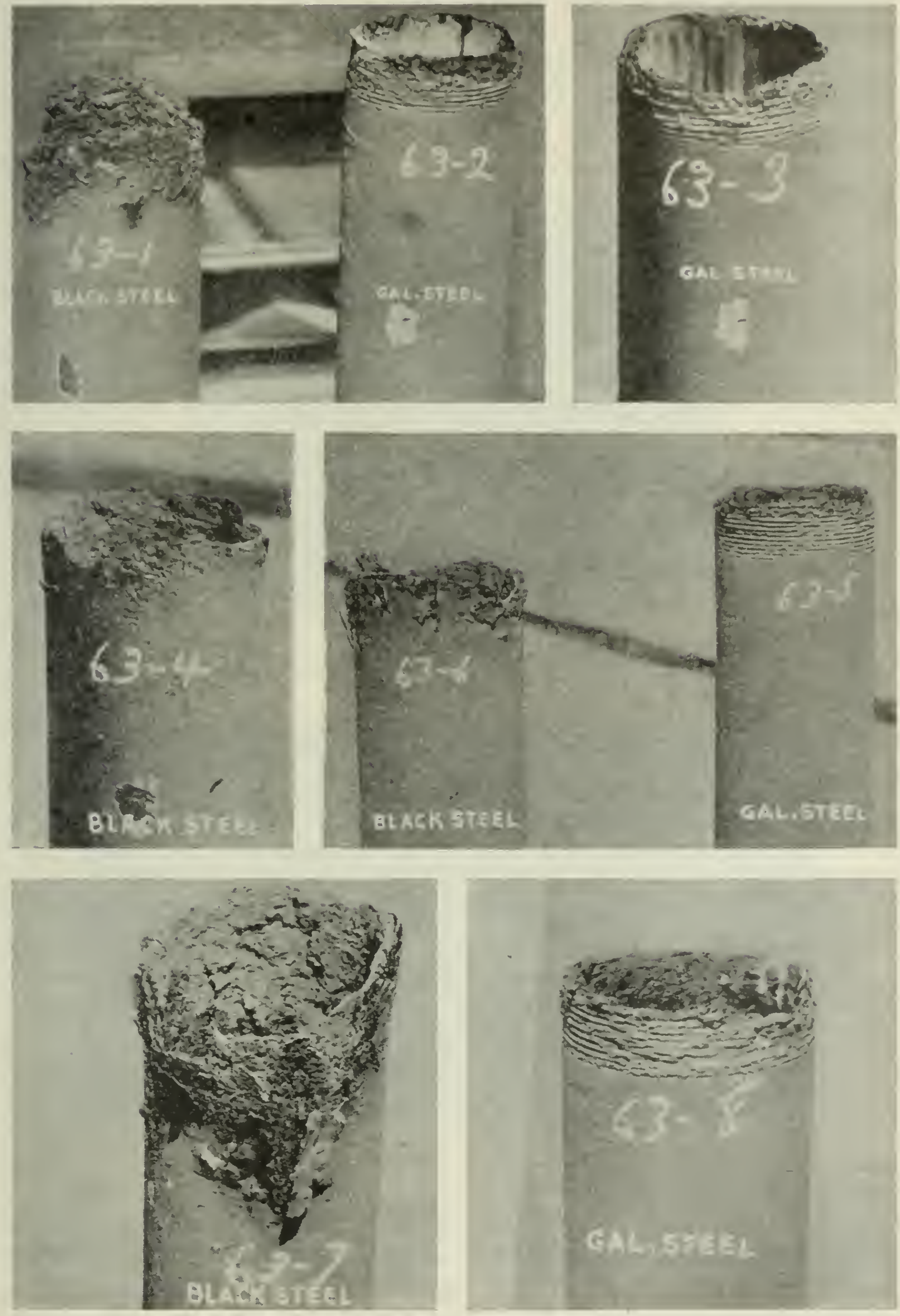
This test is an exceedingly simple chemical test and one which is particularly useful when the pipe to be tested is installed and

FIG. 3.



Wrought-iron vent pipes on roofs of Mail and Express Building after 27 years' service.

FIG. 4.

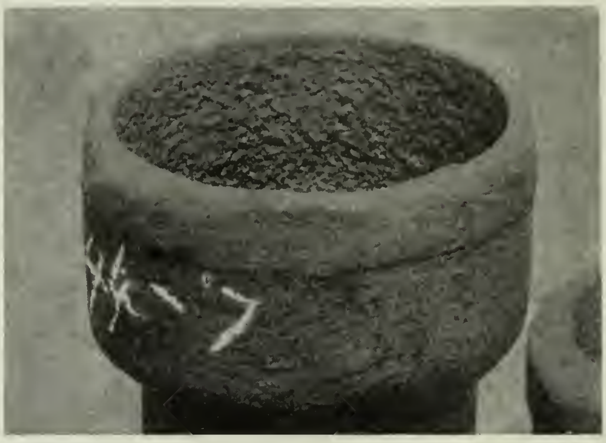


Steel vent pipes on roof of Townsend Building after 22 years' service.

cannot be removed. The test can be readily performed by any one having the necessary testing outfit, which is shown in Fig. 6.

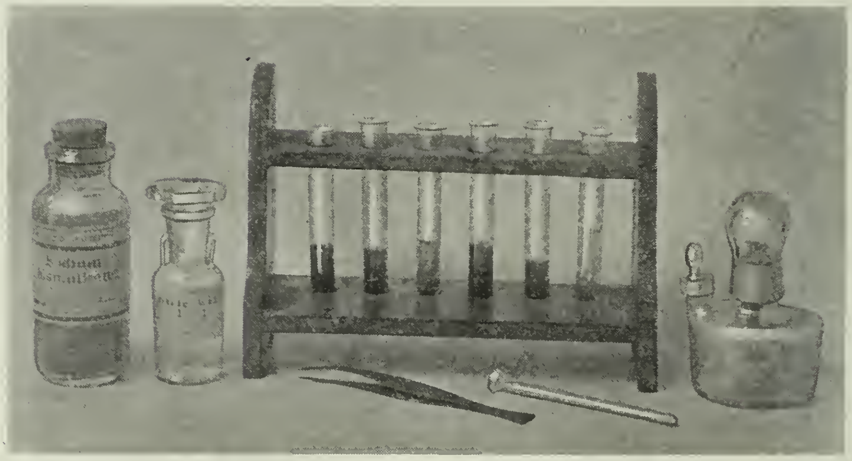
Small filings or chips from the pipe are obtained and enclosed in an envelope, marked for identification. The testing outfit illustrated consists of some glass test tubes in a wooden rack, an alcohol lamp, a pair of pincers, a small glass ladle or spoon, a bottle of nitric acid and another of sodium bismuthate. The test is made as follows: Place one chip in a test tube, add ten to fifteen drops of chemically pure nitric acid, diluted with equal parts of water, and hold the tube over the alcohol flame until

FIG. 5.



Characteristic pitting of cast iron.

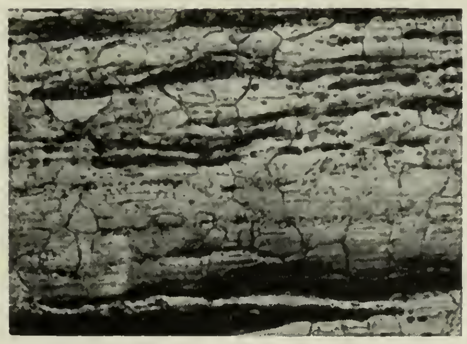
FIG. 6.



Manganese testing outfit.

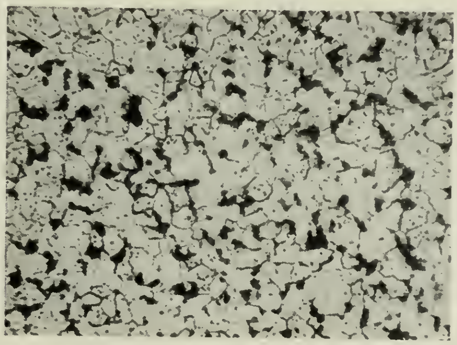
the metal becomes dissolved. Place the tube back in the rack and allow it to cool, then add a small quantity of the sodium bismuthate, enough to produce a brown residue or deposit. The solution now gives off bubbles of oxygen and then it develops a pinkish or red color, which indicates the presence of manganese, and that the pipe sample is of steel. If no reddish tint appears, but only a brown deposit in the bottom of the test tube, the sample is of wrought iron.

FIG. 7.



Micro-section of wrought iron, taken parallel to rolling.

FIG. 8.



Micro-section of soft steel.

This test is based upon the fact that in the manufacture of steel pipe ferro-manganese is added to the hot metal in the Bessemer retort to enable the rolling and welding of the steel, whereas no manganese whatever is added in the puddling process for wrought iron.

It does occasionally happen that wrought iron contains more than a trace of manganese, in which case the indications of the manganese chemical test are not to be taken without further investigation. It becomes advisable, under such conditions, to make a fracture test, or else to get a large sample of the pipe and to have its structure examined microscopically.

In my New York investigation both the managanese and the fracture tests were made, and in doubtful cases samples were referred by me to Prof. W. Campbell and to Dr. Fales, of Columbia University for a decision.

VI. THE MICROSCOPIC TEST.

This test can be made only in a physical laboratory, but it is the most decisive test of those mentioned. The sample of pipe is polished and then etched with picric acid. If it be genuine wrought iron, the metal will show the characteristic silicate slag fibres in the longitudinal section (see Fig. 7); if of steel, no slag fibres will appear, but instead the sample tested shows an even distribution of pearlite (see Fig. 8).

These are the various tests with which the writer became acquainted, though there may be others known to chemists or metallurgists.

Both steel and wrought-iron pipes, if made and sold in the past five years, can be identified by looking at the roll marks. All the largest manufacturers of welded pipe have adopted this means of having their pipe recognized by names, such as "Reading," "Byers" or "National," rolled in large letters on the outside of the pipes. If the year of manufacture is likewise rolled in, as is done by the Byers Company, this will serve in future observations or investigations to determine the length of time the pipe has been in service.

SUMMARY OF CONCLUSIONS.

The results of this investigation will be given in full in the Transactions of the American Society of Mechanical Engineers for 1917. They were likewise presented by the author at the annual meeting, on December 6th, in New York City, of the Society, and may be had in pamphlet form. They may be summarized briefly as follows:

1. Extra heavy cast-iron soil-pipe is a satisfactory material from the corrosion point of view. It is unsatisfactory as regards

the calked joints. These become affected by changes in temperature, and do not remain tight under all conditions of service.

2. The screw joint of welded pipe is superior to the calked joint, provided the threads are so cut, and the recessed drainage fittings so tapped that the pipe can be screwed well into the shoulder of the fitting. Portions of the thread remaining exposed to view should be protected against external corrosion.

3. The evidence furnished by the investigation leaves no doubt as to *genuine wrought-iron pipe being a far more durable material* for house drainage purposes *than steel pipe.*

A careful examination of the illustrations, Figs. 3 and 4, will confirm this statement. Compare the twenty-two-year-old steel pipe installation in the Townsend Building with the twenty-seven-year-old installation in the Mail and Express Building. These are only two examples out of many collected and on file.

In conclusion, I ought perhaps to state that I entered into this investigation without bias or prejudice. The results obtained should be of interest to architects and builders, consulting engineers, plumbing contractors and managers of large buildings or institutions.

New Method of Cooling Gas Engines. Anon. (*Power Plant Engineering,* vol. 22, No. 20, p. 849, October 15, 1918.)—External water-cooling is the cause of many of the disadvantages in the use of the gas engine which have retarded its development in large sizes. Experiments conducted by Professor Hopkinson of Cambridge, England, have demonstrated that the difficulties incident to jacket-cooling can be overcome by cooling the cylinder from the inside by means of water jets. When the cylinder is thus cooled, there is no heat-flow through the metal and the stresses due to unequal heating are avoided. In this method of internal cooling, cold water is injected through a hollow casing projecting into the combustion chamber and provided with a number of holes or small nozzles about 1/32 inch in diameter. The jets are directed to all parts of the surface of the combustion chamber and against the face of the piston.

Difficulties of corrosion and lubrication are overcome by regulating the quantity of water in such a way that the temperature of the cylinder is kept well above 100° C. For practical purposes, the heat-flow during the last three-fourths of the stroke is so small that direct cooling of that portion of the cylinder can be dispensed with, and it is sufficient to cool the surfaces of the combustion chamber and head of the piston only. A simple single-walled casting can be used for the cylinder, resulting in a great saving in weight and cost and in improved reliability by the elimination of casting stresses. Arrangements for cooling the piston, which are necessary in large engines, may be omitted. Finally, pre-ignitions are entirely prevented.

Water Power as a National Asset. ANON. (*Electrical World,* vol. 72, No. 28, p. 1209, December 28, 1918.)—Canada can teach us much regarding the conservation of natural resources. Her water-power sites are not only surveyed; their economic features, capacities and in many instances costs of development are known as well. Moreover, in seeking to have these resources used, the Dominion government, while it affords reasonable protection to the public, at the same time offers suitable financial reward to private enterprises. There is, however, little advantage for Canada to develop power which is transmitted to the United States, especially when there is a shortage of power in the Dominion. Many Canadians are, therefore, solicitous about her natural resources and insist that her water powers should be developed for her people. Hence the growth of immense systems like that of the Hydro-Electric Power Commission of Ontario. Inasmuch as the greater part of the population of the Dominion of Canada dwells along the St. Lawrence River valley and it is in the provinces of Quebec and Ontario that the greatest amounts of power are developed and used, the utilization of the waters of the St. Lawrence for power purposes is of immense interest to Canadians. There are no indications that the Canadians object to the joint development of the river by the Dominion and the United States or by the two provinces mentioned and the State of New York. But Canadians have a very firm conviction that none of the water should be used for private enterprises. The water may be used by local, state and national governments or by creations of those governments in the shape of public utility corporations amenable to rules and regulations of the respective states as to rates, service, etc., through commissions. A similar public opinion regarding water powers is beginning to crystallize in this country.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A PORTABLE CUBIC-FOOT STANDARD FOR GAS.[1]

By M. H. Stillman.

[ABSTRACT.]

THIS paper describes a new type of volume standard for measuring gas, which has been found to possess decided advantages as a cubic-foot standard over the apparatus of this class largely in use at the present time.

While especially well adapted to that class of work in which an inspector is required to make tests of gas-meter testing equipment distributed over a comparatively large territory, it has also been successfully used for other purposes in which the delivery of a comparatively small volume of gas with a high degree of accuracy is required.

The device is essentially a miniature meter prover, radically modified to secure accuracy and rapidity in operation and compactness in construction.

An auxiliary meter-prover scale, the use of which contributes to the accurate and convenient calibration of meter provers, is also described.

MANUAL OF INSPECTION AND INFORMATION FOR WEIGHTS AND MEASURES OFFICIALS.[2]

By F. S. Holbrook.

[ABSTRACT.]

THIS manual is designed primarily for official sealers and inspectors appointed to enforce weights and measures laws or ordinances, but it will also be of use to any one who has occasion to inspect and test weights and measures and weighing and measuring devices of the types ordinarily found in commercial use. It contains specifications and tolerances and complete instructions for the testing of all kinds of scales, length measures, liquid and dry capacity measures, etc.; general instructions concerning

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* Communicated by the Director.

[1] Technologic Papers No. 114.

[2] Miscellaneous Paper No. 1.

the enforcement of law; lists of standards and apparatus; a method of keeping office records, etc. Appendixes are included containing Federal weights and measures laws, with rules and regulations, the model State law in relation to weights and measures, a description of the metric system and general tables, conversion table and tables of equivalents.

PRELIMINARY DETERMINATION OF THE THERMAL EXPANSION OF MOLYBDENUM.[3]

By Lloyd W. Schad and Peter Hidnert.

[ABSTRACT.]

THE thermal expansion of an exceptionally pure specimen of molybdenum was determined from – 142° to + 305° C.

A short description of the apparatus and of the method used in obtaining high and low temperatures is given.

The results are shown in the form of tables, from which were computed by the method of least squares, the two following empirical equations which satisfy the observations:

$$L_t = L_0 (1 + 5.15\, t \times 10^{-6} + 0.00570\, t^2 \times 10^{-6})$$

and

$$L_t = L_0 (1 + 5.01\, t \times 10^{-6} + 0.00138\, t^2 \times 10^{-6})$$

where L_t is the length of the specimen at any temperature t within the proper range; in the first case 19° to – 142° C., and in the second case 19° to + 305° C. The probable error of the length computed from these equations is less than 3×10^{-6} per unit length.

THE DECREASE IN ULTRA-VIOLET AND TOTAL RADIATION WITH USAGE OF QUARTZ MERCURY VAPOR LAMPS.[4]

By W. W. Coblentz, M. B. Long, and H. Kahler.

[ABSTRACT.]

THE object of this present investigation was: (1) To devise methods of determining quantitatively the decrease in intensity of emission with usage and (2) to make preliminery measurements on radiant-power life-tests of quartz mercury vapor lamps.

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[3] Scientific Paper No. 332.

[4] Scientific Paper No. 330.

The measurements of the radiations from these lamps were made by means of a thermopile, in front of which was placed a 1-cm. cell of water, to absorb the infra-red rays of long wave-lengths emitted by the electrodes.

The variation in intensity of the ultra-violet rays was determined by observing the variation in transmission of a yellow, Noviol glass, with usage of the lamp.

It was found that the intensity of the total radiation, as well as the ultra-violet component, decreased to about ½ to ⅓ of its initial value in the course of 1000 to 1500 hours.

During the first 500 hours' usage no marked difference was observed in the per cent. of ultra-violet emitted by the two types (Cooper Hewitt and R. U. V. Co.) of lamps.

Data are given (1) on the variation of the total radiation emitted by quartz mercury vapor lamps with variation in energy input, (2) on the variation of the intensity of the irradiation parallel with the axis of the lamps and (3) on the variation of the intensity of the total radiation with distance from the lamps.

Comparative data are given on the ultra-violent component in the radiations from the sun, from quartz mercury vapor lamps, and also from a carbon arc lamp which is used in dye-fading tests.

MEASUREMENTS OF WAVE-LENGTHS IN THE SPECTRUM OF NEON.[5]

By Kelvin Burns, W. F. Meggers, and P. W. Merrill.

[ABSTRACT.]

THE lines in the neon spectrum are very sharp, a quality which recommends this gas as a standard source wherever the lines have sufficient strength. The ultra-violet group between 3369A and 3520A may be used for standards, and there are a few good infra-red lines, but the strength and distribution of the lines in the region 5852A to 7438A make the neon spectrum particularly useful as a comparison in this region.

The wave-lengths of fifty-five lines in the neon spectrum have been measured by means of the interferometer. These lines lie in the region 3369A to 8495A. The strong lines in the visible region of the spectrum have been observed with great accuracy.

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[5] Scientific Paper No. 329.

the probable error being one part in several millions, or less than one-tenth the width of the line. These strong lines were observed by means of three different pairs of interferometer plates, which were each used on several interferometers. The ultra-violet lines and all the strong lines in the visible were compared directly with the fundamental standard 6438A. Some of the deep red and infra-red lines were compared with well-determined lines in the visible neon spectrum.

One hundred and eighty-nine faint lines in the visible and infra-red neon spectrum have been measured by means of a concave grating. The probable error of these grating measurements is one or two hundredths angstrom. The region covered by the grating observations extends from 5343A to 8783A.

The constant differences discovered by Watson are found to hold with remarkable exactness in the case of lines which are strong enough to be measured with the highest accuracy. In fact, the differences are exactly constant within the limits set by the accuracy of the wave-lengths.

A Target Practice Airplane. Anon. (*Scientific American*, vol. 129, No. 26, p. 511, December 28, 1918.)—An American aircraft builder has introduced a diminutive airplane which flies itself without the aid of any human hand to guide it, and can therefore be used as a target, thus bringing realism and efficiency to the aerial gunnery schools. The airplane is of the Burgess-Dunne type, modified to meet the conditions for which it was designed. Inherent stability is obtained by employing a large sweepback and negative dihedral angle. The course of the machine is governed by setting and locking the control surfaces in position prior to flight.

The little machine is of the seaplane design to facilitate starting and alighting. It has a span of 18 feet 5 inches with a cord of 28 inches. The length is 9 feet, while the overall height is 4 feet 8 inches. Although the weight of the complete machine is only 175 pounds, it is capable of carrying a man. The power plant consists of a 12-horsepower four-cylinder motorcycle engine which has been rebuilt to meet the special requirements. The propeller is 42 inches in diameter, mounted as a "pusher." While climbing the diminutive airplane develops a speed of 40 miles per hour, which rises to 50 when flying on a level keel.

NOTES FROM THE INSTITUTE OF INDUSTRIAL RESEARCH.*

LIEUTENANT-COLONEL ALLERTON S. CUSHMAN, Ordnance Department, U. S. A., has just received his honorable discharge from the Army. For eighteen months he had charge of the research and chemical laboratories, including the explosive activities, at Frankford Arsenal, Pennsylvania, where he was engaged principally on ammunition and metallurgical problems. He now returns to his former professional activities as head of this private research institution, where his services, as well as those of the entire personnel and the laboratory facilities, will be at the disposal of clients.

The other members of the Institute staff have also resigned from various branches of war service in which they were engaged. Former Lieut. Henry A. Gardner, U. S. N., is a distinguished expert on paints, varnishes, etc.

Dr. George W. Coggeshall, chemical engineer with the Emergency Fleet Corporation, is expert on concrete, waterproofing, plant design and extension and general chemical engineering problems. Dr. Coggeshall specialized during the war on concrete ship construction, including oil-proofing and water-proofing.

Mr. H. C. Fuller, who is well known in pharmaceutical and food problems, takes up again the control of the food and drug laboratories of this Institute.

All these gentlemen return from their war service work, to which they made valuable contributions and in which they gained added knowledge and experience, with a very strong belief that this country has before it a great industrial future. The value of the service of chemistry and chemical engineering has been so definitely proved during the war that it seems certain that our manufacturers will turn naturally for expert and scientific work to institutions of a nature similar to our own.

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* Communicated by the Director.

The Ferro-Alloys. J. W. RICHARDS. (*General Electric Review,* vol. 21, No. 11, p. 751, November, 1918.)—A large industry has grown up within the last fifty years, most of it within the last twenty-five years, which furnishes steel makers alloys of iron with some of the rarer metals. It is quite commonly known that the addition of these metals to steel greatly improves its qualities for special purposes. These ferro-alloys were originally made in crucibles, cupolas or blast furnaces, but are now made principally in electric furnaces and their manufacture is now one of the principal electric furnace industries. They are of great importance to the steel industry. The steel maker uses them for one of two purposes: (1) As reagents to take oxygen out of melted steel and thus insure sound, solid casting. For this purpose, ferromanganese, ferrosilicon, and ferroaluminum are employed. (2) To add to the steel a small or large percentage of the rare metals, ferromanganese, ferrochromium, ferrotungsten, ferromolybdenum, ferrovanadium, ferrotitanium, ferrouranium, ferroboron.

Melted steel, just before it is taken from the furnace, always contains some dissolved oxygen (like the dissolved gas in charged soda water). The addition of a small amount of metal with a high affinity for oxygen removes this element and makes the casting sound. Manganese (1 per cent. or less) is the cheapest and most generally used reagent; silicon (½ per cent. or less) is more powerful but also more expensive, and is often used to supplement the action of the manganese; aluminum (0.1 per cent. or less) is still more powerful and expensive, and is used in very small quantities as a final addition to complete the action of the manganese and silicon. All steel makers use one, two, or all three of these reagents; manganese and silicon in the form of ferro-alloys; aluminum more often as the pure metal, though ferroaluminum is sometimes used.

When a sufficient quantity of the rare metal is added to the steel, it acquires properties different from plain carbon steels deoxidized by manganese, silicon, or aluminum. Thus, a very tough, hard steel, such as is used in mining and grinding, burglar-proof vaults, etc., may be made by the addition of 12 to 14 per cent. of manganese. Chromium (2 to 4 per cent.) makes a very hard tool steel; tungsten (15 to 25 per cent.) makes a high-speed tool steel which, while red hot, cuts iron. Vanadium (0.1 to 0.5 per cent.) makes a very strong steel which resists shock extremely well, as when used for automobile axles; titanium, uranium and boron also impart valuable properties. Every one of these materials produces some specific result; sometimes two, three or four are used for producing a specific combination of special properties. Some of these materials cost $5 per pound, and the special steels produced cost up to $2.50 per pound, but their particularly valuable properties justify the expense.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting Held Wednesday, December 18, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 18, 1918.

PRESIDENT DR. WALTON CLARK *in the Chair.*

Additions to membership since last report, 4.

Reports of progress were presented from the Committee on Library, and the Committee on Science and the Arts.

The following nominations were made for officers and managers to be voted for at the annual election to be held on January 15, 1919:

For President (to serve one year), Walton Clark.

For Vice-President (to serve three years), Henry Howson.

For Treasurer (to serve one year), Cyrus Borgner.

For Managers (to serve three years), Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Nathan Hayward, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, E. H. Sanborn.

The paper of the evening, entitled "Vehicular Tunnels Under the Hudson River," was presented by Mr. Martin Schreiber, Member American Society of Civil Engineers, Chief Engineer, Public Service Railway Company, Newark, N. J. A general outline was given of the traffic conditions at the port of New York as far as they affect the necessity for vehicular tunnels under the Hudson, or North River. Descriptions were given of the various official bridge and tunnel plans thus far proposed. The important engineering phases were discussed, especially those relating to the ventilation of tunnels. The paper concluded with a résumé of the present status of the project. In the discussion which followed the paper Messrs. Alleman, Chance, Crisfield, Lindenthal, Modjeski, the Chairman, and others participated.

After a vote of thanks to the speaker, the meeting adjourned.

GEORGE A. HOADLEY,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Amram, Philip W., 2nd Lieut.	Student Army Training Corps	Harvard Univ.
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Billings, A. W. K., Lieut. Com.	Chief Engineer, U. S Naval Forces (Aviation)	London
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N. R.F.	New York
Brown, Lucius P., Captain	Sanitary Corps, Division of Food and Nutrition	Camp Greenleaf
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Capt.	Ordnance Dept., U.S.R.	Washington
Clark, Beauvais, Sergeant	108th Field Artillery	France
Clark, E. B., Major	Gas and Flame Service, A.E.F.	France
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	France
Clark, Walton, Jr., Capt.	Field Artillery	France
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., Captain	Air Service, U .S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div., A.E.F.	France
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade

Name and rank	Branch of service	Location
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force	Philadelphia
Gribbel, W. G., Captain	Co. A., 30th Engineers, U.S.R. (Gas and Flame)	France
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Captain	E.O.R.C., 23rd Engineers	Camp Laurel
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Senior Master Engineer	488th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 2nd Lieut.	5th Engineers	Camp Lee
Kingsbury, E. F., Captain	Air Service Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Madison, Wis.
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U.S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	Infantry R. C.	Camp Meade
McMeekin, C. W., Major	Army War College	Washington

Name and rank	Branch of service	Location
Martin, Thos. S., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Casper W., Major	Medical Corps Division of Food and Nutrition	Washington
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Pemberton, Henry R.	U. S. Naval Air Service	Key West, Fla.
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineer Officers' Reserve Corps	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase. Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Ulmer, Carl D., Private	Chemical Warfare Service, A.E.F.	France
Vogleson, J. A., Major	Sanitray Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Ensign	U. S. Navy	
Weyl, Charles N.,	U.S.N.R.F.	Philadelphia
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers	3rd Officers' Training Camp	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Railway Artillery Reserves	France
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York

Name	Appointment	Location
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Gudeman, Edward	Emergency Fleet Corporation	Chicago
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Washington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Humphreys, Rich'd L.	Director of Building Materials, Building Materials Div., War Industries Board	Washington
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington

Name	Appointment	Location
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Rittmann, Walter F.	Consulting Chemical Engineer, U. S. Bureau of Mines	Pittsburgh
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William F.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting Held Wednesday, December 4, 1918.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 4, 1918.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for first reading:

No. 2727: Stabilized-Platform Weighing Scale of Novel Design.

The following report was presented for final action:

No. 2723: Prestwich Patent Fluid Gauge. Recommended that the Edward Longstreth Medal of Merit be awarded to John Alfred Prestwich, of Tottenham, London, England.

GEORGE A. HOADLEY,
Acting Secretary.

SECTIONS.

Electrical Section.—A joint meeting of the Section and the Philadelphia Section, American Institute of Electrical Engineers, was held in the Hall of the Institute on Thursday evening, November 7, 1918, at 8 o'clock. As the Chairman of the Electrical Section was the speaker of the evening, the meeting was presided over by Mr. George R. Henderson.

Mr. W. C. L. Eglin delivered an illustrated lecture on "The Power Company." Mr. Eglin began by giving figures showing that the electrical industry ranked fourth according to the value of its products. He then showed by figures and graphic illustrations how the industry grew in number of employees, size of generating units and output. Particular reference was made to the system of the Philadelphia Electric Company, showing by means of a diagram the A. C. and D. C. distributing systems, high-tension transmission lines, the street railway supply and the railroad electrification. Views were also shown of the newest types of generating stations in various parts of the country.

On account of the meeting occurring during the evening of the day on which it was rumored that the armistice, terminating the World War, had been signed, the attendance was unusually small. After a brief discussion the meeting adjourned.

H. CALVERT,
Secretary.

Section of Physics and Chemistry.—A joint meeting of the Section and the Philadelphia Section, American Chemical Society, was held in the Hall of the Institute on Thursday evening, December 5, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read. The program for the meeting of December 10th was announced.

Edgar F. Smith, Ph.D., Sc.D., Chem.D., Litt.D., L.H.D., LL.D., Blanchard Professor of Chemistry in the University of Pennsylvania, and Provost of the University, delivered a lecture on "Chemistry in Old Philadelphia," describing the life and contributions to chemistry of deNormandie, Rush, Priestley, Hutchinson, Woodhouse, Coxe, the Seyberts, T. P. Smith, Cooper, Troost, Keating, Cloud, and Hare. A résumé was given of the growth of industrial chemistry in Philadelphia. The lecture was illustrated with lantern slides, and the balances of Priestley and the lock and key of his home were exhibited. Several members and visitors participated in the discussion. A vote of thanks was tendered Provost Smith, and his paper was referred for publication.

Mr. Hance introduced Captain S. N. Lemon, of the Canadian Army, who described the use of gas in warfare by the Germans. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Tuesday evening, December 10, 1918, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were read and approved.

Joseph W. Richards, Ph.D., Professor of Metallurgy in Lehigh University, Secretary of the American Electrochemical Society, and Member of the U. S. Naval Consulting Board, gave an address on "The Vapor Tensions of the Metals." A résumé was given of the available data concerning the vapor tensions and the boiling points of the metals, and of the analogies between the vapor tensions of metals and of other elements and compounds. Methods were outlined for the calculation of the vapor-tension curves of metals in both the solid and the liquid state. The value of this information in pure science, in metallurgy, and in various uses of the metals was discussed and illustrated.

The communication was discussed by Messrs. Penrose and Clamer, Professor Snyder, Drs. Alleman and Richards, and others. On motion of Dr. Walton Clark, the paper was referred for publication. A vote of thanks was tendered Doctor Richards, and the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, December 11, 1918.)

RESIDENT.

MR. JOSEPH BUNFORD SAMUEL, Retired Iron Merchant, 1609 Spruce Street, Philadelphia, Pennsylvania.

MR. LESLIE D. SMITH, Chemist, 309 South Frazier Street, Philadelphia, Pennsylvania.

NON-RESIDENT.

DR. JOHN HUNT WILSON, Professor of Chemistry, Lafayette College, and for mail, 531 Cattell Street, Easton, Pennsylvania.

ASSOCIATE.

MR. RICHARD ASHBY MARRIOTT, Student, Rensselaer Polytechnic Institute, and for mail, Young Men's Christian Association, Troy, New York.

CHANGE OF ADDRESS.

MR. THOMAS BILYEU, in care of Astoria Marine Iron Works, Astoria, Oregon.

MR. W. J. CRAGO, in care of Fajardo Sugar Company, Fajardo, Porto Rico.

MAJOR VICTOR LENHER, 158 Summit Avenue, Madison, Wisconsin.

MR. FREDERICK W. SALMON, 274 Wellington Avenue, Auburn, Providence, Rhode Island.

MR. CARL D. ULMER, 162 East Water Street, Middletown, Pennsylvania.

MR. HENRY W. WILSON, 909 Clinton Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

American Society for Testing Materials.—A. S. T. M. Standards. 1918.
Croy, Homer.—How Motion Pictures are Made. 1918.
Durand, W. F.—Practical Marine Engineering. Ed. 7. 1918.
Dyson, C. W.—Screw Propellers. 2nd ed. 2 vols. 1918.
Flying Book.—Edited by W. L. Wade. 1918.
Gregory, H. E., ed.—Military Geology and Topography, 1918.
Klein, A. W.—Kinematics of Machinery. 1917.
National Association of Railroad Commissioners.—Proceedings, Vol. 29. 1917.
Richards, J. W.—Metallurgical Calculations. 1918.
Severance, H. O., comp.—Guide to the Current Periodicals and Serials of the United States and Canada. Edition 3. 1914.
Sleeman, C. W.—Torpedoes and Torpedo Warfare. 1880.
United States Catalogue. Supplement.—Books published 1912–1917.
Whelen, Townsend.—The American Rifle. 1918.

BOOK NOTICES.

Bibliography of American Literature Relating to Refrigeration, with Synopsis of Papers and Reports Covering the Year 1915. Compiled by Peter Neff under the direction of the Committee on Papers and Lectures of the American Association of Refrigeration. 107 pages, paper covers. 8vo. Chicago, Illinois, published by the Association.

The large amount of valuable information contained in the files of technical periodicals, much of which is available only by laborious consultation of yearly indexes, offers an extensive field for the work of the bibliographer which has not yet been adequately covered. The author of this compilation and the society which sponsored it are rendering the profession a valuable service in publishing a bibliography of current literature on refrigeration.

The work is more than a bibliography, it contains also a section devoted to book reviews, and a collection of abstracts, the latter covering 76 pages. In the bibliographic section, brief synopses of subject matter are given. The book reviews are unabridged. The abstracts give at considerable length a very satisfactory résumé of the topics recorded. Indexes under title, subject and author are included.

The Committee state that if the present volume meets with approval, it is their purpose to publish a volume for each succeeding year, and to prepare a synopsis of all literature published on ice and refrigeration previous to 1915. It is stated that the appearance of the volume has been delayed by war conditions. The 1916 Bibliography has been delayed for the same reason, but is now in press and will be issued at an early date.

The work can scarcely fail to prove of great value, and it is to be hoped that the Society will be induced to carry out the comprehensive plan outlined.

Lucien E. Picolet.

PRACTICAL PHYSIOLOGICAL CHEMISTRY. By Philip B. Hawk, M.S., Ph.D., Professor of Physiological Chemistry and Toxicology in Jefferson Medical College. Sixth edition, revised and enlarged, 634 pages, contents and index, four additional full-page colored plates and one hundred and eighty-five figures, of which twelve are in colors, 8vo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $3.50.

A book which has in eleven years gone through six editions, including two reprintings, must find a want and meet it satisfactorily. Indeed, every one who is familiar with Doctor Hawk's work is fully aware of its merit. Physiologic chemistry is a rapidly growing phase of science, and is already so complex as to require a great deal of close study and accurate experimentation to secure any familiarity with it. This book will be a highly satisfactory guide to both the student and practical chemist. One of the most interesting chapters is that on enzymes. A vivid synopsis is given of our present knowledge (and want of knowledge) on this important subject. The presswork, printing, proofreading, and especially the color-plate work, are all excellent, and the text is throughout clear and explicit. The book is another evidence of our enfranchisement from using as text-books mere translations from foreign authors.

HENRY LEFFMANN.

INTRODUCTION TO ORGANIC CHEMISTRY. By John Tappan Stoddard, Professor of Chemistry at Smith College. Second edition, 411 pages, contents and index, 12mo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $1.50 net.

This is a readable and concise summary of the leading data of organic chemistry as now taught in American schools. The endeavors of the author as expressed in the preface are well met, facts and theories being presented "simply, directly and connectedly, so that the student may gain a clear idea of the principles of organic chemistry and its relations to general chemistry." The text is relieved of much detail by tables giving names, formulas and properties of many groups of compounds. The treatment of the important groups of alkaloids and protein seems too brief. The section on enzymes is more satisfactory, but should have been put with proteins. The book is well printed with clear type, but the margins are rather narrow, and, in the copy in the reviewer's hands, several signatures have been obliquely trimmed, giving an unpleasant appearance to the page.

HENRY LEFFMANN.

THE CHEMISTS' POCKET MANUAL. By Richard K. Meade, M.S. Third edition, 514 pages and index, 16mo. Easton, Pa., The Chemical Publishing Company, 1918. Price, $3.50.

This compact book, convenient for laboratory use, contains a large amount of information, principally, of course, as with all such manuals, in the form of tables and constants. Considerable space is, however, devoted to analytic methods along industrial lines, many of the recent methods developed by American chemists in the great industrial districts of the eastern part of the country being included. The principal value of such a book will be in the selection of subjects, the freedom from typographic errors and clearness of printing. The volume in question meets these requirements very well. It is probable that the methods are given too briefly in some cases, and it is doubtful if laboratory workers seeking information on analytic methods will consult a work of this type, but rather the standard works. It is for the tables that the book will be most used, yet there is a large amount of useful information on standard analytic methods presented. On page 310 "anilin" is accidentally spelt "analine," and on page 436 a solution of "hydrochlorid of naphthylamin" is given as one of the reagents for detecting nitrates, while on page 297 the reagent is given as "alpha-naphthylamin acetate." The latter is the correct form.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

University of Kansas, Bulletin: Engineering Bulletin No. 10. The Present Development of Transmission Lines in Kansas, with Appendix: The Calculation of Iron Wire Lines, by F. Ellis Johnson. 53 pages, illustrations, plate, map, 8vo. Lawrence, Kansas, University Engineering Experiment Station, 1918.

United States Tariff Commission: Tariff Information Series, No. 8. The Brush Industry. Commercial and Industrial Conditions in the United States and in Foreign Countries. Tariff Laws Affecting Brushes. Court and Treasury Decisions. 77 pages, 8vo. Washington, Government Printing Office, 1918.

U. S. Bureau of Mines: Monthly Statement of Coal-mine Fatalities in the United States, August, 1918. List of Permissible Explosives, Lamps, and Motors Tested prior to September 30, 1918; compiled by Albert H. Fay, 27 pages, 8vo. Bulletin 129, The Fusibility of Coal Ash and the Determination of the Softening Temperature; by Arno C. Fieldner, Albert E. Hall and Alexander L. Feild. 146 pages, illustrations, plates, 8vo. Bulletin 171. Mineral Technology 23. Melting Brass in a Rocking Electric Furnace; by H. W. Gillet and A. E. Rhoads. 131 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1918.

North Carolina Geological and Economic Survey: Economic paper No. 48. Forest Fires in North Carolina During 1915, 1916 and 1917, and Present Status of Forest-fire Prevention in North Carolina; by J. S. Holmes, State Forester. 97 pages, 8vo. Raleigh, State printers, 1918.

Introduction to Organic Chemistry, by John Tappan Stoddard. 2nd edition, 423 pages, 12mo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $1.50.

CURRENT TOPICS.

Renovation of Discolored Arc-lamp Globes. A. Hertz. (*Electrical World*, vol. 72, No. 20, p. 935, November 16, 1918.)—It is common knowledge that in certain cases after new glassware has been installed on street-lighting units, a very obnoxious discoloration has occurred in a comparatively short time. The glassware which suffers most is that subjected to the rays from arc lights rich in short ray-lengths, such as the magnetite arc. The most common discoloration is purple which is present only where the artificial light strikes the glassware, such places as are shielded from the lamp rays being clear, even after long use, aside from the coloring brought about by the rays of the sun. The amount of the discoloration depends upon three factors: (1) The composition of the glass; (2) the amount of violet and ultra-violet light present; (3) the time of exposure.

The glass subject to this discoloration usually contains some form of iron, commonly Fe_2O_3, in some cases amounting to 6 per cent. This glass in its natural state is colored slightly green, and various means have been tried for neutralizing this coloration. Manganese compounds are found to be commercially most satisfactory for this purpose. Purple, the characteristic color of manganese, when added to the green in the original glass, produces a very thin black cloud which absorbs some of the light, usually 10 to 15 per cent. Under the action of certain light, the purple manganese color itself becomes prominent, entirely over-balancing the green in the iron. Since this purple color entirely penetrates the body of the glass, it is at once apparent that a pickling or washing process is useless. Having observed that the color could be removed from pieces of broken globes by heating, further experiments were made, and it was found that these globes could be entirely cleared up by a careful heat-treatment. An annealing process carried out at a temperature of 900° F. was found to remove the color without causing softening or distortion of the globes. The annealing seemed to reform the manganese compound into its original condition so that the glassware again became clear.

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MODERN APPLICATIONS OF PHOTOGRAPHY.*

BY

ALFRED B. HITCHINS, Ph.D., F.R.P.S., F.R.M.S., F.C.S.,
F.R.S.A., F.Ph.S.L.,

Director of Ansco Research Laboratory, Binghamton, N. Y.
Member of the Institute.

THE word "photography" means to sketch or draw by light; thus a photograph is a record of the chemical activity of light upon a sensitive surface. A photographic emulsion, which is the light-sensitive medium, is prepared by precipitating silver bromide, silver iodide or silver chloride in gelatine, either separately or in combination, according to the character of the emulsion desired. The precipitate thus obtained is exceedingly fine and is held in suspension in the gelatine solution forming an emulsion. This emulsion is coated upon glass, celluloid or paper, according to the purpose for which it is intended. Negative emulsions, such as are used in the camera, are made with silver bromide, and in some cases a small proportion of silver iodide. They are extremely sensitive to light and form the basis of all our photographic operations. When a plate or film is exposed in the camera to the image formed by a lens, a change takes place in the silver halide under the action of light, and the change is proportionate to the intensity of the light at any part of the image; in other words, a developable or latent image is formed. It is not proposed to discuss the theories of the latent image. Scientists have been speculating upon its composition for years,

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* Presented at the Stated Meeting of the Institute held Wednesday, November 20, 1918.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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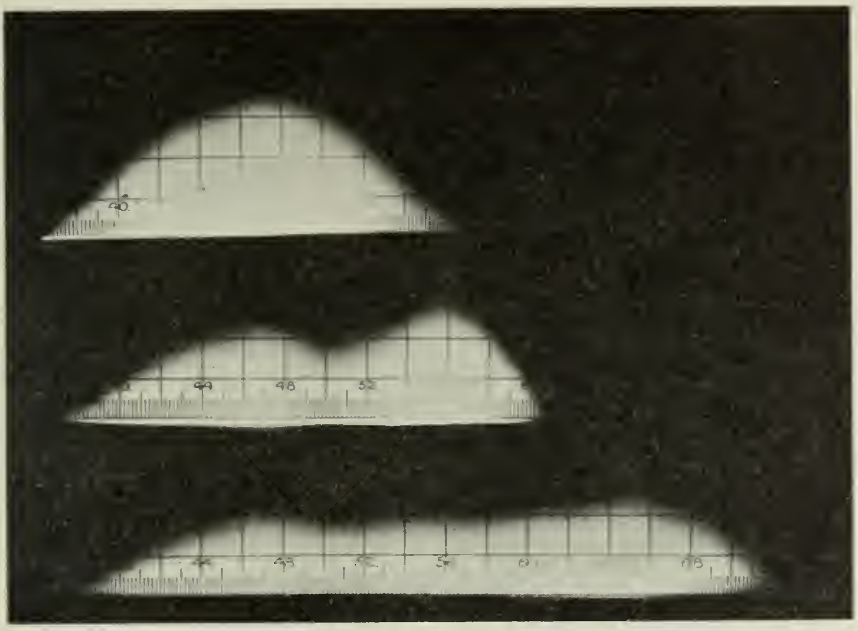
and at the present time no one really knows of what it is composed or how it is formed. It is sufficient to know that under the action of light a definite change takes place in the silver halide, rendering it susceptible to development, with consequent reduction to metallic silver which forms the finished photographic image. The image so obtained is a negative, that is to say it is the reverse of the original—white is rendered as black, and black as white. The negative, when dry, is printed upon a photographic paper which is usually coated with a silver chloride emulsion. The negative is brought into intimate contact with the silver chloride paper and exposed to a light source. The paper is affected in proportion to the opacities of the negative and upon development yields a print in monochrome, which is a correct representation of the object photographed.

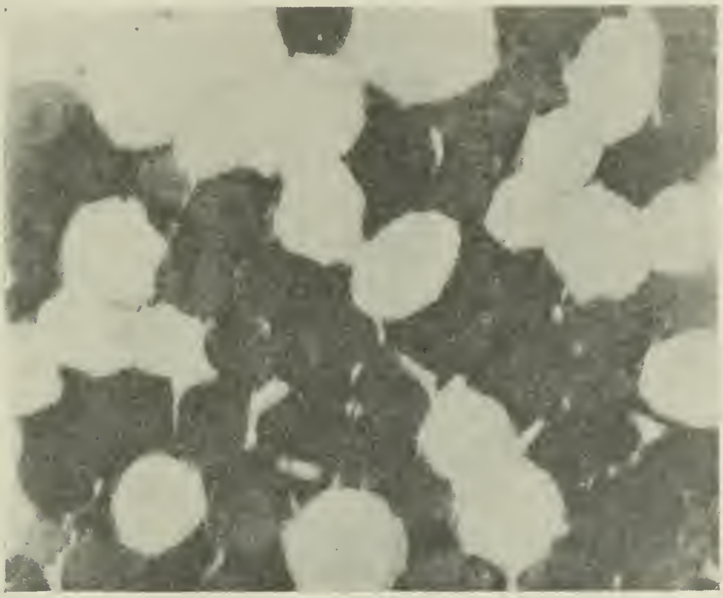
The most common uses of photography are in portraiture and pictorial representation. It is not necessary to discuss these applications of photography. The work of the professional and amateur photographer is familiar to everyone. It will be as well at this point to explain one of the peculiarities of ordinary photography. The eye is affected most by yellow, orange and green rays, and to some extent by red rays, which therefore appear bright to us; the ordinary photographic plate is practically insensitive to these rays, so that they appear dark in photographs. Blue and violet, on the other hand, have a very small effect upon the eye and appear dark to us, but they most strongly affect the photographic plate and therefore appear as white in the photograph. At that portion of the plate where the blue part of the image falls, photographic action takes place and density in the negative results and is rendered as white on the print; at that part of the plate where the yellow, orange or red image falls little or no photographic action occurs, because the plate is not sensitive to these rays. This results in practically clear glass, which, when printed, yields a dark gray or black, and a photograph under these circumstances is contrary to the visual effect. Had it not been found possible to sensitize a photographic emulsion for colors other than blue and blue-violet, photography would have found but little application in the sciences and arts because of its untruthful rendering. Happily, however, methods have been discovered of rendering the photographic emulsion sensitive to practically the whole spectrum. This subject naturally leads us to a consideration of color-correct photography; that is, the possibility of rendering in monochrome color luminosities as seen by the eye. These points can be best explained by illustration. Fig. 1 shows a series of photographs of the spectrum upon various photographic emulsions. These were made in a spectrograph having in front of the slit a graduated black glass wedge which grades the exposure across the width of the spectrum band and so automatically plots the curve of color-sensitiveness. Curve I was made upon an ordinary or non-color-sensitive emulsion. The maximum sensitiveness is in the blue and there is practically no action beyond blue-green. Such an emulsion, as previously described, will not render color luminosities truthfully. Curve II was made upon an orthochromatic plate. Emulsions are rendered orthochromatic by the addition of a dye to the emulsion, usually erythrosine. The silver bromide grain is dyed and sensitiveness is conferred in the region of the color absorbed by the dye; this results in a secondary maximum in the yellow-green. Such an emulsion, when used with a yellow screen, will approximately render color luminosities as seen by the eye. Curve III shows a photograph of the spectrum made upon a panchromatic emulsion. Panchromatic means sensitive to all colors of the

FIG. 1.



spectrum, and this quality is obtained by bathing a silver bromide emulsion in various dyes, usually of the isocyanine group; the dyes most commonly used being homocol, pinaverdol and pinacyanol. One of the chief uses of panchromatic plates is in the practice of the so-called commercial photography and embraces such subjects as the reproduction of paintings, stained glass, tapestries, various-colored woods, in fact, any subjects which are multi-colored and where it is necessary to render correctly color luminosities in monochrome. When working with panchromatic plates, it is possible by the use of compensating or contrast color filters to subdue or emphasize any particular color; that is to say, we may at will increase or decrease detail in any particular color region. A very important use of panchromatic emulsions is in three-color photography. This process is in general use for the illustration of our books and magazines, and is dependent upon the use of panchromatic plates in conjunction with certain selective color filters. Three selective negatives are made of the subject through a red, green and blue-violet filter respectively. From the selective negatives so obtained, printing plates are prepared which are inked up with inks of a color complementary to the taking filters. The color images are printed one on top of the other in perfect registration, and the resulting composite print is a fairly accurate reproduction of the original colored object. The practice of tri-color photography calls for a highly specialized knowledge and a great deal of manipulative skill, and is confined to a few specialists who are thoroughly equipped for the work. There is, however, another process of direct-color photography known as the screen-plate method which may be practiced very successfully by the ordinary photographic worker. There are several screen plates upon the market, but up to the present time the most perfect is the autochrome process of Lumierè. Three batches of potato starch grains are dyed red, green and blue-violet respectively, and after dyeing, the starch cells are intimately mixed in the proportion of four green to three red and two blue. By an ingenious coating machine the mixed grains are spread on glass plates, flattened out by rollers to fill in the interstices and then varnished. Upon this color screen a panchromatic emulsion is coated. Fig. 2 shows the structure of the color screen. This illustration is a photomicrograph magnified 800 diameters. It will be seen that the whole of the plate is covered with a large number of microscopic tri-color screens. When such a plate is exposed in the camera with the glass side turned towards the lens, so that the microscopic screens intercept the image before it falls upon the panchromatic emulsion, we obtain a result shown diagrammatically by Fig. 3.[1] A red object absorbs green and blue and emits only red rays. These pass through the red elements of the screen and act on the silver bromide emulsion behind them. The film at that point will be blackened during the course of development; the excess red rays will be absorbed by the blue and green elements of the screen, and no change takes place in the film behind them. If the object is green, the rays will be absorbed by the red and blue elements of the screen, and the film behind the green elements will be blackened upon development. A yellow object emits green and red rays; these will be absorbed by the blue elements, but will pass through the red and green ones. White light will pass through all the screens, and upon development the film will be blackened behind all three elements. A black object reflects but little light, and the developed negative will not show a deposit under any of the screens. It is obvious that if this process is stopped at the negative stage the results, when viewed by transmitted light,

FIG. 2.



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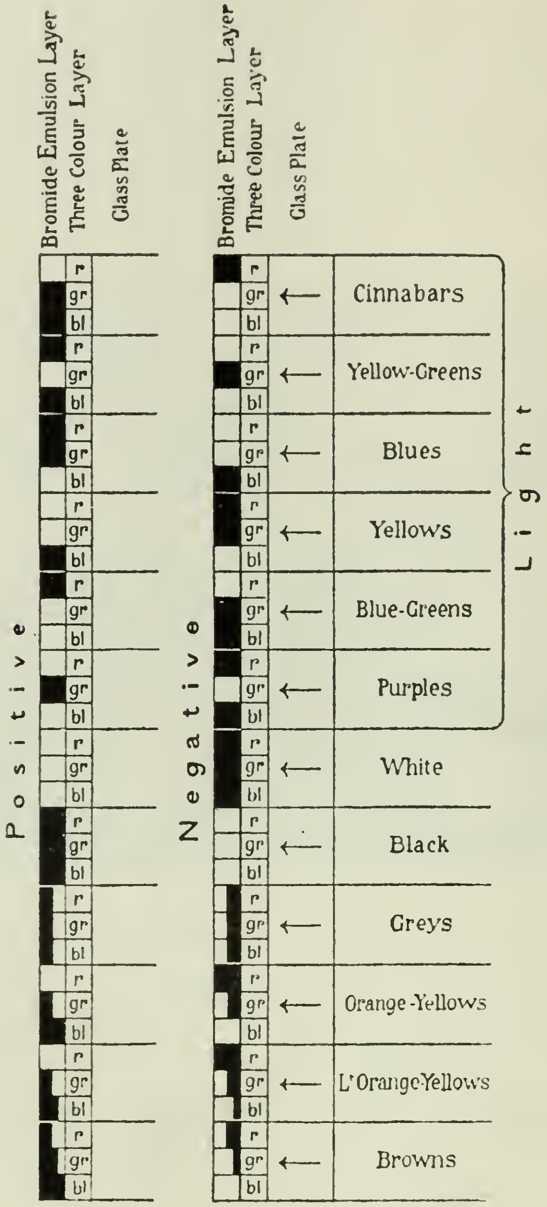
[1] From "Photography in Colors," by Dr. Lindsay Johnson.

will be in colors complementary to the original. The negative is, however, reversed by a chemical process which dissolves away the whole of the blackened silver deposit; the plate is then exposed to light and redeveloped, when the whole of the silver bromide particles, which had not been acted on originally, will now be reduced to blackened silver and a positive image will result, revealing the true colors of the original, because where, for instance, the red, green and blue images fell, the red, green and

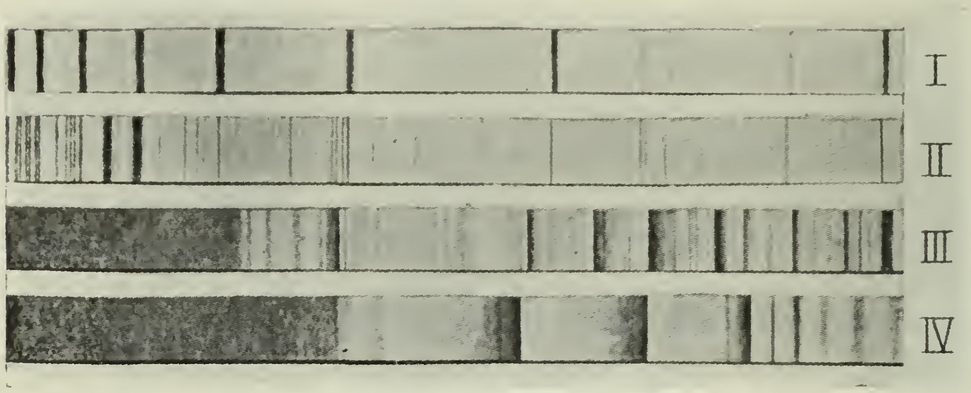
FIG. 3.



blue grains are free from silver deposit, and by transmitted light we shall see these colors. Mixed colors are formed by partial backing up of one or more of the screen elements, and the plate viewed as a whole is a faithful reproduction of the original colors. Autochromes can be made in an ordinary camera. The only additional apparatus necessary is a yellow-taking filter, which is placed in front of the lens during exposure to cut down the activity of the blue rays. The starch grains are between .01 and .02 mm., or about the size of a white blood-corpuscle, so that to the eye the plate is practically structureless. The various other screen plates to be obtained are all based upon the same principle as the autochrome, that is, the whole of the plate is covered with microscopic tri-color screens—the only difference being that in some cases the composite color screen is of geometric design; in some cases it is made up of circles, and in others straight lines.

Now, let us consider photography as applied to spectrum analysis. When light passes through a slit and is spread out into a band of colors—violet, blue, green, yellow, orange and red—the result is called a spectrum, and the instrument that effects such an analysis of light, a spectroscope. When light from a white-hot, solid, non-volatile substance is examined with a spectroscope, a full or continuous spectrum is observed; all the colors are shown and there are no gaps. Volatile substances generally give off light of very much less complexity; for instance, the metal thallium, when heated in a flame, gives a certain green light that cannot be decomposed, and thallium is the only substance which produces light of exactly this character, so that when such light is observed we know that thallium is present to produce it. Sodium gives a particular yellow light which is not obtained with any other substance. Most substances, when their vapors are made to glow, give very complex lights, and their spectra show a number of fine lines, and from the number and position of these lines we can with certainty tell what substance gives rise to them, for no two substances, when their vapors are luminous, have ever been found to give the same spectrum. If spectra are observed by the eye, it is obvious that we must be limited to light that affects the eye—that is, to visible light—but we can photograph not only all visible light, but a great deal more that extends in the spectrum beyond the violet at one end and the red at the other. Photography has, therefore, provided us with a means of obtaining a permanent record that can be measured at leisure and has extended vastly the range of spectroscopy, bringing out facts that never could have been known without its aid. Such photographs render with wonderful accuracy an enormous number of fine closely packed lines. The use of specially prepared emulsions in conjunction with spectroscopic instruments having optical systems of quartz has enabled the ultra-violet region to be very thoroughly studied and mapped. Another very important application of spectro-photography is in connection with astronomy. By means of photography we have been able to detect double stars that are so close together that the most powerful telescope would not reveal them as two distinct stars. When one star is approaching us and another receding from us, each line in their spectrum will be doubled, the two new lines being one on each side of the single line that will be seen when both stars are moving at right angles to the line of vision. The line that is displaced towards the blue end of the spectrum represents the shortened wave length due to the approaching star, and the line displaced towards the red end the increased wave length due to the receding star. The rate at which the stars are moving from us or towards us can then be calculated from the displacement of the line. Fig. 4 shows spectro-photographs of the four typical stellar spectra, according to the classification of Secchi. Secchi made spectroscopic examinations of a very large number of stars and found that all stellar spectra could be classed under one or the other of four types. Secchi's Type 1, or the Sirian type, includes most

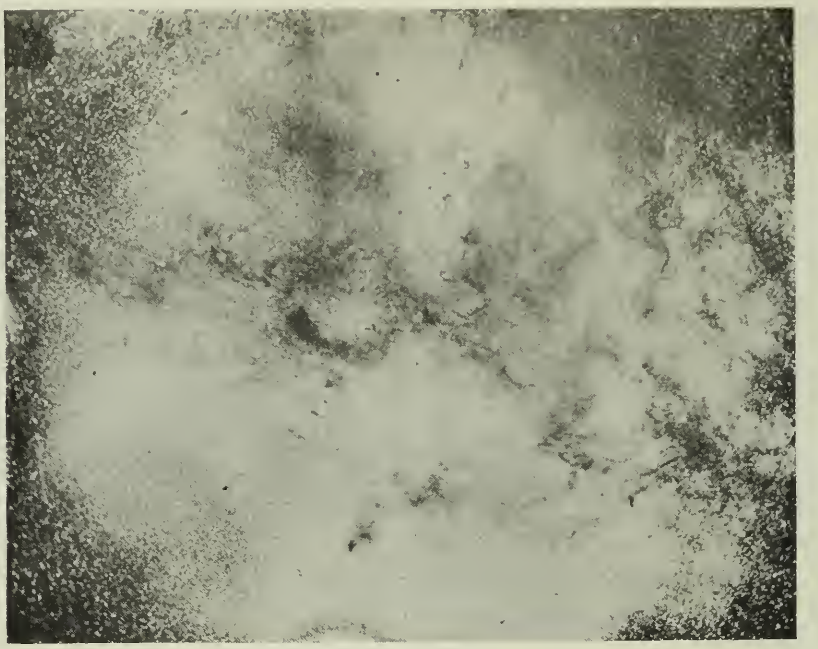
FIG. 4.



of the bright white stars. Type 2 includes the solor stars; Type 3, the stars of reddish color, most of them variable stars. The spectra of stars of Type 3 show flutings or bands of lines sharply bounded on the violet side and falling off towards the red. It has been shown that these flutings are due to titanium oxide. Type 4 also consists of red stars with banded spectra, but the bands differ in arrangement and appearance from those of the third type and are sharply bounded on the red side. These stars are believed to have a comparatively low surface temperature, and the flutings are attributed to the presence of carbon. Passing now to the more purely astronomical applications, such as the photography of the sun, moon or stars: The planet Mars is particularly interesting to us, because it resembles in many ways our own terrestrial process. When either of the Martian polar regions come into view after being turned nearly a year away from the sun, it is found to be covered with a white cap. This gradually decreases in extent as the sun shines upon it during the remaining half of Martian year—sometimes nearly disappearing. This change is so obviously due to the precipitation of watery vapor in the form of ice, snow or frost during the winter and its melting or evaporation when exposed to the sun's rays, that such a conclusion has never been seriously questioned. The general sandy yellow appearance of Mars is considered to be due to vast deserts, and the green markings due to vegetation. Mars has been most thoroughly studied by means of photography, and much valuable data obtained.

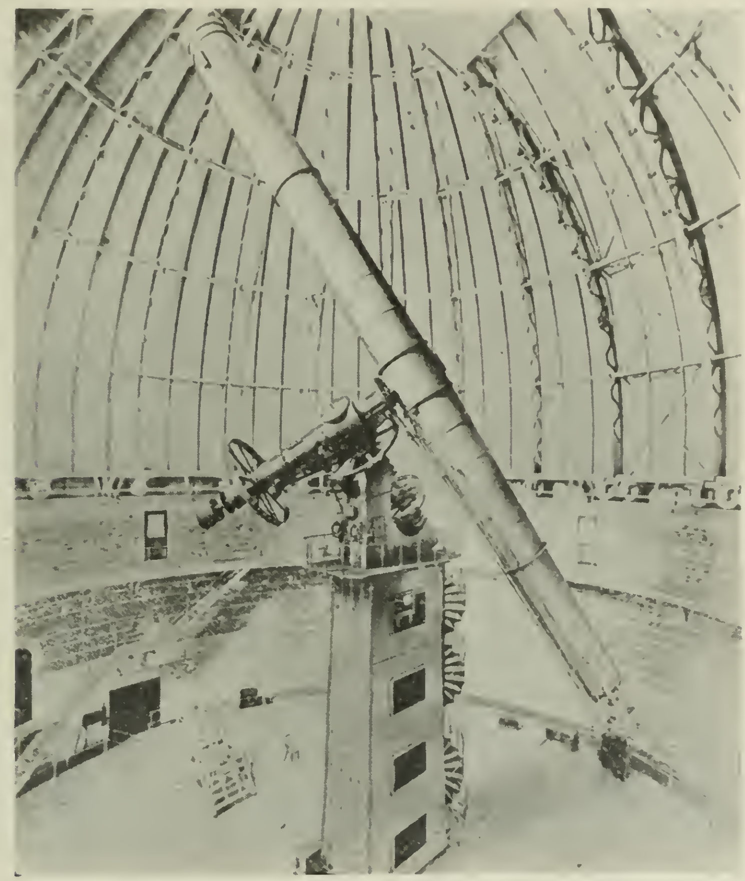
Another very beautiful subject for photography is the great Nebula in Orion. The Nebulæ are luminous cloudy patches in the heavens. They resemble the stars in that they retain the same relative positions. When examined with sufficient telescopic power, a great many of these luminous patches are perceived to be composed of clusters of little stars. Fig. 5 shows a portion of the "Milky Way" to the north of Theta Ophiuchi. In this particular region are some of the most wonderful dark markings in the sky. Photography has been of inestimable value in the study of the moon, a very complete photographic chart of its various regions having been secured. By means of the spectroheliograph, some very wonderful photographs have been made of solar prominences. These prominences are huge gaseous streamers flaring out from the body of the sun, and they are frequently sixty to seventy thousand miles in length. The spectroheliograph is an instrument by which photographs may be made of the sun's body in light of any particular chosen wave length. The solar prominences are usually photographed in the monochromatic light of the red hydrogen line. Fig. 6 shows the 40-inch refractor at the Yerkes Observatory. It is with this wonderful telescope that most of the finest astronomical photographic work has been done. This huge telescope is capable of the most precise movement; clock-work and electrical devices are provided by means of which the telescope may be made to follow exactly the path of a star. This is necessary in stellar photography, otherwise the image of the star would move across the photographic plate during the comparatively long exposure. By moving the telescope in unison with the star's movement, the image is kept perfectly still on the photographic plate. Photography has been of the very greatest use in the development of astronomy. A number of stars that are quite invisible through the most powerful telescope have been discovered and studied.

FIG. 5.



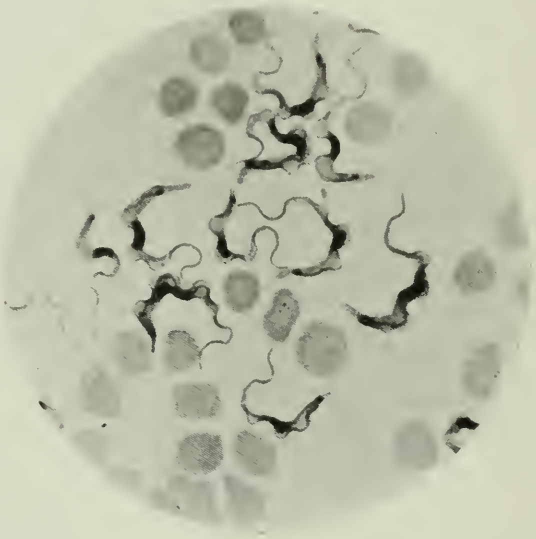
Another application of photography, which is of considerable interest to scientific workers, is photomicrography—that is, securing a photographic record of the enlarged image seen through a microscope. The ordinary lens is for this work replaced by the miscroscope itself. The camera is similar in all respects to an ordinary camera. One of the most important things in photomicrography is to secure adequate and critical illumination. In this work it is nearly always necessary to use panchromatic plates, for most microscopic objects are colored. By the use of proper color filters any particular portion of a microscopic section can be subdued or emphasized. This is important in connection with the rendering of structure. Photomicrography is applied to medicine in the study of pathological conditions, to bacteriology, insect anatomy, metallurgy and to many other industrial and scientific studies. Fig. 7 shows a photomicrograph of bacteria. These are the trypanosoma of sleeping sickness, found in the blood, and when in living condition actively motile by an undulatory movement of their protoplasm and a lashing of the flagellum. Photomicrography as applied to pathology is of great

FIG. 6.



importance. In practically every large pathological laboratory hundreds of photomicrographs of normal and abnormal pathological conditions are made yearly. These form a permanent record for the education of the student and the convenience of the pathologist. Such photomicrographic studies have brought about many improvements in the methods of detecting, treating and preventing organic diseases. Fig. 8 is an example of photomicrography applied to the study of insect anatomy. This is the tongue of the common house-fly, and is one of the most wonderful illustrations of the beauties of insect anatomy. The fly's tongue is the small black object which everyone has seen a fly let down onto sugar, syrup or any of the sweet things he delights in. The large lobes contain the suctorial tubes; these tubes are wonderfully constructed. They have within them a spiral support very much like the coiled wire used for supporting and strengthening rubber gas pipe. The two brushes are those that he uses to clean up with after his meal.

FIG. 7.

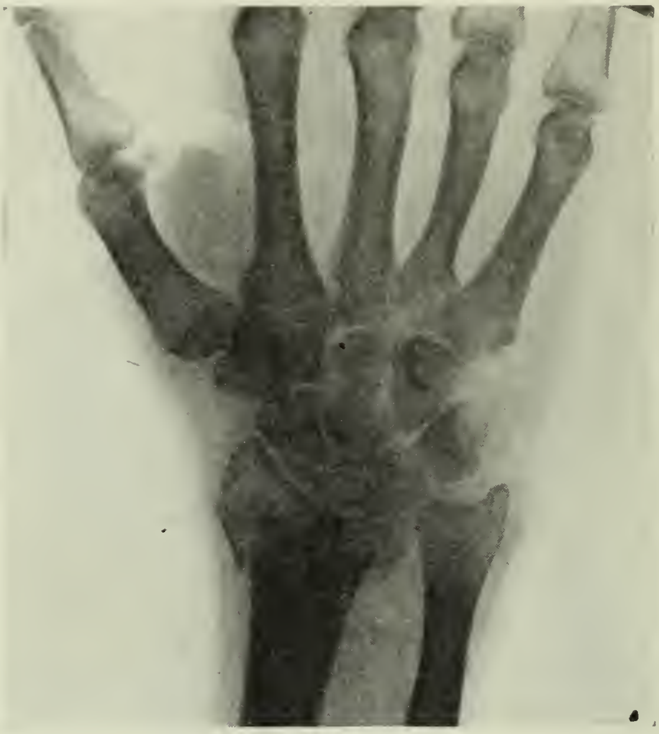


One of the most valuable aids to medicine as a diagnostic agent is the practice of X-ray photography. Until quite recently considerable experimenting with apparatus and accessories was necessary for every operator before he felt at all confident of making a reasonably good X-ray photograph, but now instruments have been devised by which the time of exposure required can be determined with mathematical exactness and under all conditions, and it has become a far easier proposition to produce really good radiographic plates. X-rays are produced by the discharge of a high potential current through a special form of vacuum tube known as a Crookes tube. There being no method of bringing X-rays to a focus, the images produced on a photographic emulsion are merely shadows of the object. The vacuum tube is brought within a reasonable distance of the patient in proper relation to the part to be photographed. The photographic plate in its black envelope is placed under the patient. The exposure necessary varies a great deal, according to the structure of the part to be radiographed; also the vacuum tube must be chosen with a view to the results desired. A soft or low vacuum tube gives much better definition than a hard or high vacuum tube, as the rays pass less easily through dense substances and show greater differentiation of tissue. A very high vacuum tube may show but little difference between the bones and flesh, while a soft tube should give the minute structure of the bones. Most tubes in these days are fitted with regulators for controlling

FIG. 8.

the vacuum. Fig. 9 shows an X-ray photograph of a hand and forearm. Fig. 10 is a radiograph of the complete skull, and shows very nicely the details of bone structure. These radiographs were made with the instruments made by the Kny-Scheerer Company. For X-ray photography a special emulsion is necessary. It must be capable of giving contrast, and must be thickly coated upon the glass or celluloid support. In some cases, where the use of glass plates is awkward, owing to the shape or curvature of the particular part to be radiographed, films may be used, and in dental radiography films are always used. In practically every large hospital there is a complete radiographic equipment, and regular studies are made of the bodily functions, particularly peristalsis. The patients are fed with a meal containing a substance which is opaque to X-rays, and therefore distinctly shown in the radiograph. By this means the process of digestion may be accurately studied.

FIG. 9.

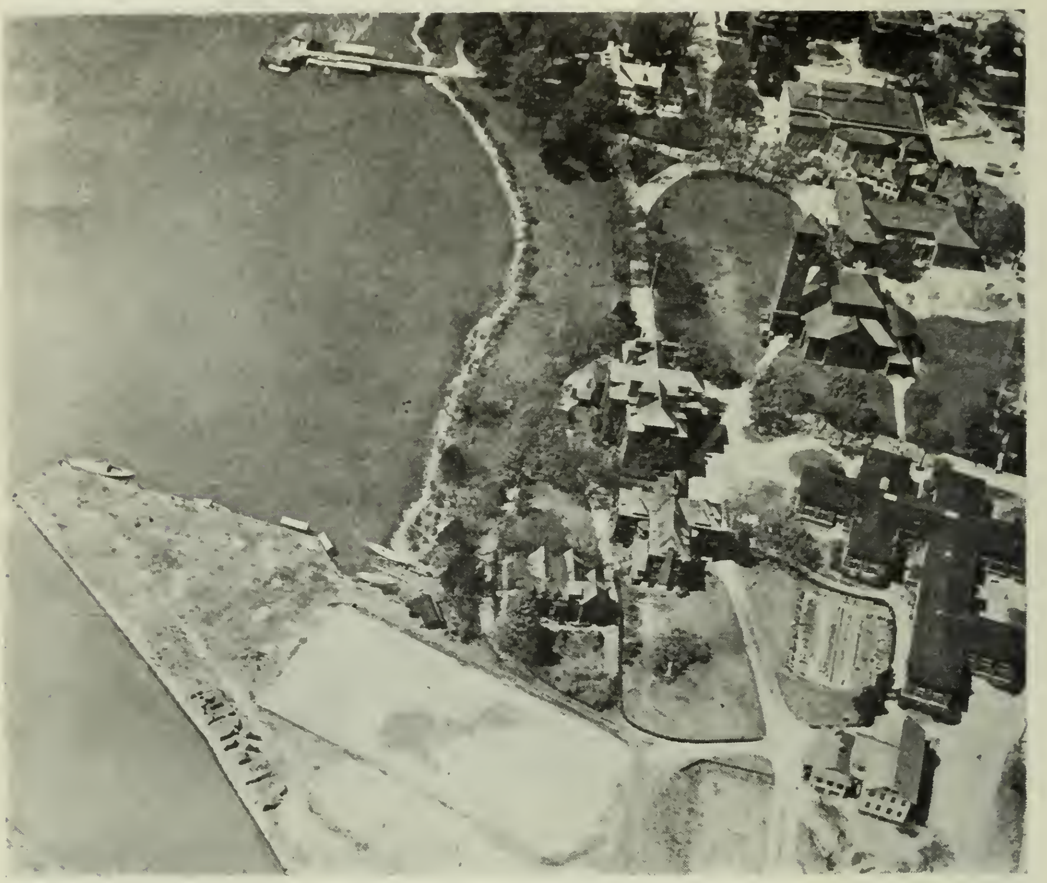


As a source of amusement and pleasure the application of photography to motion-picture work is of great importance; but of still greater importance is the application of motion-picture photography to scientific studies and for educational purposes. Motion-picture photography is now being used for recording surgical operations. The efficiency engineer uses it for motion study, and it is of the greatest use in teaching biology, natural history, chemistry, physics and countless other subjects. Governments of practically all nations have official cinematographers whose duty it is to record events of national and historical importance. These are preserved in vaults for the benefit of posterity, and will undoubtedly be of the greatest importance to future historians. Forestry and agricultural conditions are also recorded in motion pictures by various bureaus of the United States Government.

FIG. 10.

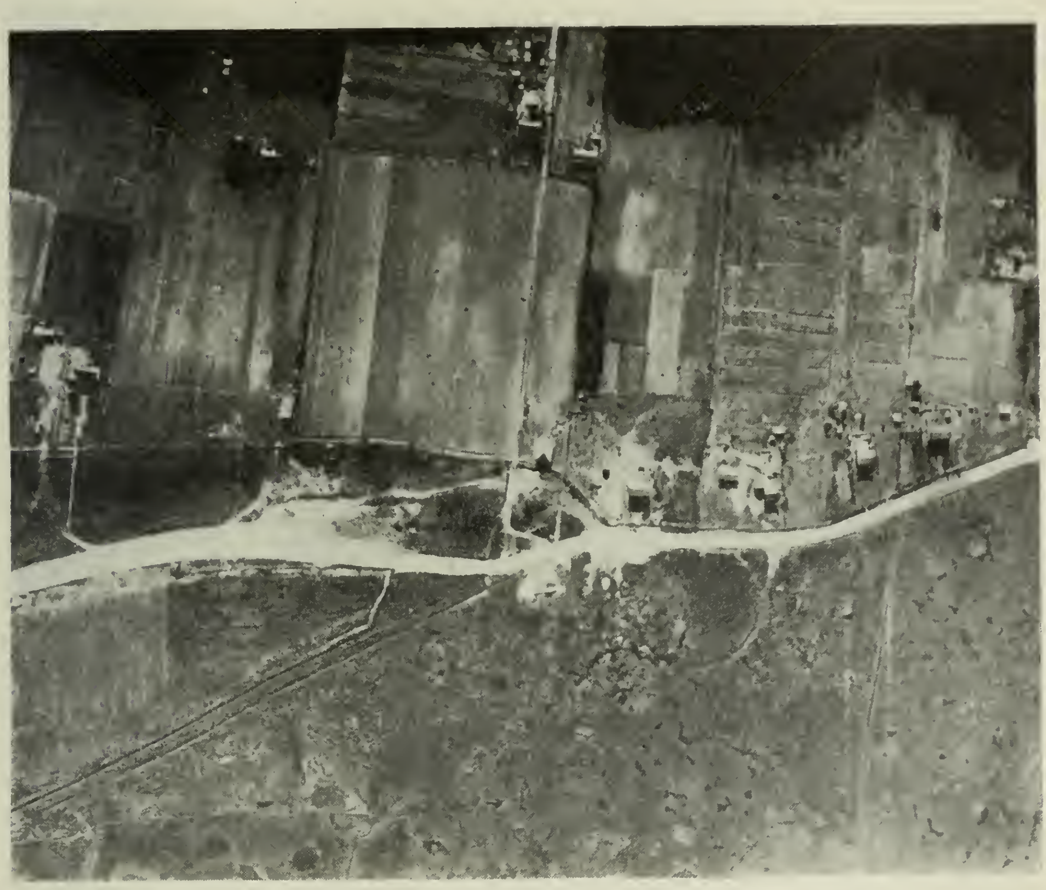
The war has perhaps done more than anything else to bring about improvements in photographic practice. Photography has been of such vital importance to the successful prosecution of the war that the best brains have been working upon the improvement of the various photographic processes. Aeroplane photography has perhaps been of the most direct service in the war. It has made it impossible for the enemy to carry out any extensive movement without detection, and the aerial photographs secured of enemy territory have been of the utmost use in securing the success of our attacks and the safety of our men. It has been my privilege to be associated with the Signal Corps and the Science and Research Division in a great deal of experimental work in connection with war photography. Much of this work has been directed towards the production of suitable emulsions for aeroplane work. For instance, emulsions which will detect all the colors used in camouflage and specially sensitive emulsions so that photography may be carried out on hazy days when the unaided eye sees practically nothing. From the very beginning the work has been of absorbing interest, and led to a great deal of physical and photographic research. Through the courtesy of the Military Censor, I am permitted to publish one or two illustrations of aerial photography. These are illustrated in Figs. 11, 12 and 13. These pictures show the wealth of detail that can

FIG. 11.



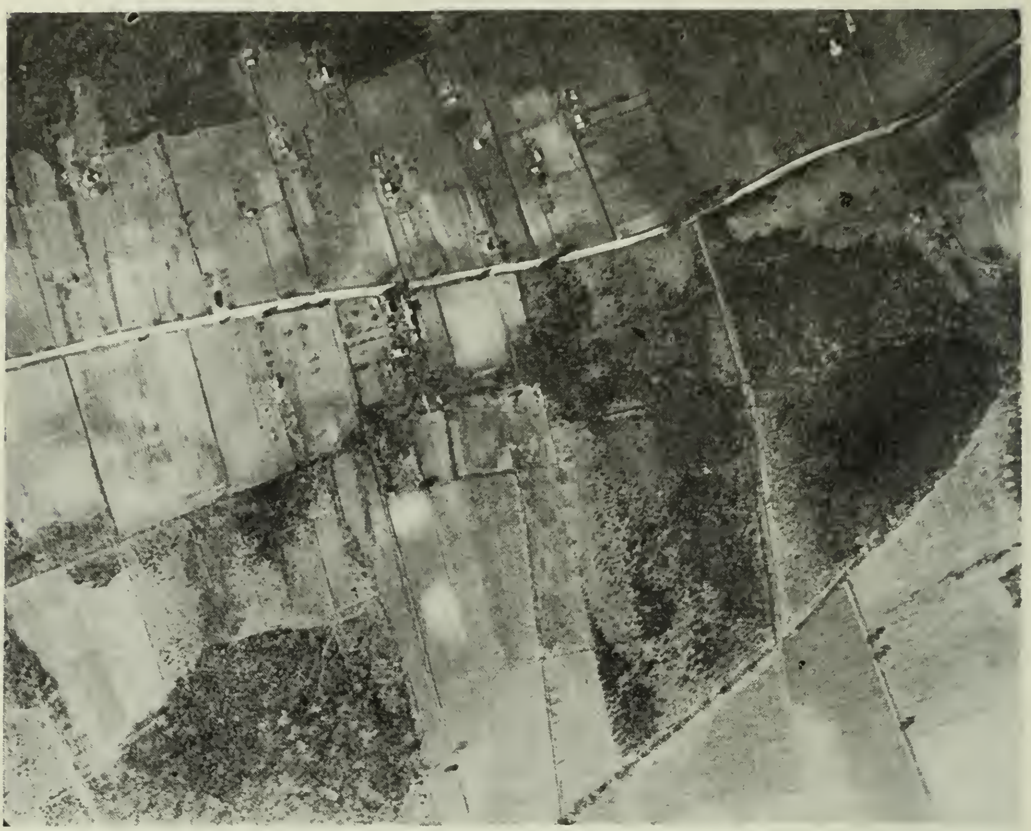
be secured when photographing from a plane. It is such pictures that have revealed the enemy's trench system, their gun emplacements, and have shown our officers the lay of the land, so that they might the better direct their attacks. Early in the war aerial photographs were made at an altitude of seven or eight thousand feet, but with the increasing range of anti-aircraft guns it became necessary to adopt a much higher altitude for photographic observation, and recently most pictures have been made at from twelve to fifteen thousand feet. There is no doubt that this country and her allies are going to take advantage of the many uses of photography to a much greater extent than before the war. Aerial photography will undoubtedly be used in the future to replace the older methods of survey and mapping. Some wonderful cameras have been constructed for aeroplane photography—some of them operated by hand in the ordinary way, and some of them automatic, the exposure being controlled

FIG. 12.



from the instrument board of the plane. One of the finest automatic cameras—the Brock camera—was developed and made in Philadelphia. Only a few of the many applications of photography have been discussed in this paper, and these only in a superficial way, without entering into any details of the photographic theory and practice involved. To deal fully with the many applications of photography would fill many volumes. In addition to the few applications of photography discussed, it is used for such subjects as meteorology, the study of cloud formation, and the photography of lightning. By means of the telectrograph, photographs may now be transmitted over a telegraphic system. Photography is used for the recording and detection of criminals. A camera is the constant companion of the explorer, and the trusted recording medium of the naturalist, the geologist and other scientific workers. In fact, photography is now generally recognized as the accurate and invaluable recorder of progress in science, art and industry.

FIG. 13.



THE CONCEPT OF RESILIENCE WITH RESPECT TO INDICATING INSTRUMENTS.*

BY

FREDERICK J. SCHLINK, M.E.

Associate Physicist, U. S. Bureau of Standards.

I. CLASSIFICATION OF INSTRUMENTS.

For the purposes of the present treatment, measuring instruments may be grouped in the following large classes:

I. Indicating instruments.
  1. Index-and-scale instruments.
  2. Comparison instruments, read by reference to a fiducial mark.

II. Value-controlling instruments, usually non-indicating.

III. Totalizing, aggregating or integrating instruments.

Class I–1 includes instruments using a mechanical pointer or indicator traversing a fixed scale; instruments in which the kinematic relation is reversed, wherein a scale moves past a fixed pointer or reference mark; and instruments in which a surface of discontinuity, such as a liquid meniscus, traverses a fixed scale (as in barometers) or a moving scale (as in hydrometers). In each case the motion of the index relative to the scale may be one of either translation or rotation or of any required combination of the two.

The class of comparison instruments (I–2) overlaps the index-and-scale class in most cases, since a graduated scale having a short range of value equivalents is commonly applied at either or both sides of the fiducial mark or zero, as is familiarly instanced in the case of the precision balance. The graduated arc over which the pointer plays typifies the scale of an indicating instrument used for a range of capacities normally but a minute fraction of the total working capacity of the balance, which if the graduations other than the zero be omitted becomes a comparison instrument, strictly. This short-range indicating feature usually appears on comparison instruments for the reason that, exact equivalence of any two quantities being a practically impossible occurrence, it is desirable to know, except in the roughest commercial measurements, not merely that the quantities compared are equivalent, but the amount of the deviation from exact equivalence, as a differential value or correction.

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* Communicated by the Director, U. S. Bureau of Standards.

Class II includes instruments most familiar to the engineer, such as carburetors, wherein the flow of air is to be accommodated mechanically to the flow of fuel; thermostats and hygrostats; voltage regulators; automatic damper regulators for boiler furnaces; governors for steam engines, spring motors and other prime movers—and many others.

The instruments of the last main class (III) will not be further considered in the present discussion. This class comprises those in which the indication afforded represents the accumulation of values registered up to the time of observation. As examples may be mentioned gas and water meters, watthour meters and clocks.

The treatment of the present paper is particularly concerned with the instruments comprised in Classes I–1 and II, but relates also to a limited extent to that part of Class I–2 in which the combination of the scale and comparison instrument occurs in the manner already exemplified.

In an earlier paper [1] the general principles underlying the definition and determination of those types of variant errors in the indications of mechanical measuring instruments inherent in the defects of the instrument itself, and not *per se* indicative of change in the value of the quantity undergoing measurement, were discussed. To errors of this type I have applied the term *variance.* They typify the sort of errors which are not subject to avoidance by the application of corrections in the ordinary sense of the word, and have in the past been somewhat loosely referred to, when mentioned at all, as instrumental vagaries or perturbations. It was shown in the paper above referred to that the variance could be well expressed by plotting the relation between the quantity undergoing measurement and the indication of the instrument for a series of gradually increasing and then decreasing values of the former, so obtaining a representation of the deviation from consistent indication in the form of a hysteresis loop.

An interesting independent corroboration of the results shown in the previous paper with regard to the general form of the calibration loop was found in the literature of the steam engine indicator. The appended Fig. 1 is reproduced from the diagram on page 179 of Houghtaling's "Steam Engine Indicator and Its Appliances." It represents the calibration of an indicator carried out by causing the pencil to trace a short line at each of a designated series of known unit pressures applied to the piston, for a cycle of increasing and decreasing values of pressure. It will be noted that the pairs of lines corresponding to a given pressure, while coincident at the lower and upper ends of the scale, are somewhat displaced mutually at the other readings, and that they tend definitely to a wider mutual displacement toward the middle or upper region of the scale. It is clear that if this particular calibration were replotted with displacements of the pencil as ordinates and unit pressures as abscissæ, a loop of the type discussed in this and the previous paper would result, closed at the ends and widening out at the middle. Limitations of space prevent the reproduction of other experimental data tending to illustrate the characteristic closed loop, but it may be said that a large number of indicator calibrations giving results of precisely similar form are to be found in another text-book on the steam engine indicator.[2]

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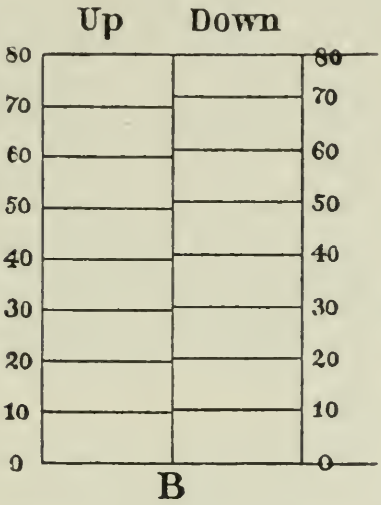
[1] "Variance of Measuring Instruments and Its Relation to Accuracy and Sensitivity," Scientific Paper 328 of the Bureau of Standards.

FIG. 1



In this connection the steam engine indicator seems to afford a particularly fortunate corroboration, since that instrument comprises in a well-known manner, resulting from long development in the hands of able instrument makers, one of the most favorable types of elastic force-resisting elements (usually a helical spring) in combination with an indicating train consisting of a linkwork of several jointed bars driving a frictionally opposed recording pencil—so that the indicator assuredly comprises causes of hysteresis associated with both elastic and mechanistic[3] phenomena. The indicator then, in this sense, may be deemed typical of indicating instruments generally in so far as any one instrument can be said to represent a group comprising a diversity of constructional elements and combinations.

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[2] See page 28 of "Practical Instructions for Using the Steam Engine Indicator," published by Crosby Steam Gage and Valve Company, Boston, 1917.

II. HYSTERETIC CYCLES—THE PROPERTIES OF THE GRAPH—THE NATURE OF INSTRUMENTAL HYSTERESIS.

In the present paper it is desired to give more detailed discussion to the consideration only suggested in the previous work, *viz.,* the concept that an indicating instrument, in so far as it consists of mechanical elements, is a mechanical complex capable of storing and restoring energy, and that the perfection of its resilience in this exchange, which, as will be shown, may be taken as a measure of its excellence as regards the invariance of its indications, is to be measured by the smallness of the area of the hysteresis loop obtained in the calibration of the instrument over a range of successively increasing and decreasing values of the quantity which it is to measure, the results being plotted in the manner already described.

As in the case of the hysteresis loop of strained quasi-elastic bodies and of material undergoing dielectric or magnetic induction, the hysteresis loop obtained when an instrument is subjected to a complete cycle of operation represents by its area, generally speaking, the amount of energy lost or dissipated during a cycle.[4]

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[3] The term "mechanistic" is used to characterize phenomena due to the mechanism itself, and not to the single components of the mechanism. Its use enables us to discriminate, for example, between causes of lag arising in imperfect elasticity and those due to imperfect mechanical operation of the linkwork considered as a mechanism.

[4] If the instrumental lag does not involve a significant time effect, the input of energy represented by a given slow deflection is a quite definite quantity or at least can be specified to lie within certain determinate limits. (This is a reasonable supposition in any event, but the author hopes to establish its verity on a sound experimental basis in a forthcoming paper. If a time lag intervenes, the energy loss in the instrument of course depends upon the frequency of the cycle, just as it does to a certain extent in other hysteretic phenomena, such as the stress-strain relation of such substances as rubber, leather, etc.)

Turning to Fig. 2, we are enabled at once to set down certain simple and useful relations and definitions which will be of value in gaining the greatest amount of information from the complete calibration curve (of two branches, forming a closed loop) for any given indicating instrument. For the sake of generality, an instrument affording both positive and negative indications has been assumed, such as might be typified by a dynamometer so constructed as to measure both traction and thrust, or an ammeter provided, as is not uncommon, with scales reading in opposite directions from a central zero.

Area $BCDD'_y \asymp$ (equivalent to) energy required to produce deflection D_y when quantity undergoing measurement changes from B_x $(-)$ to D_x $(+)$.[5]

Area $BEDD'_y \asymp$ energy returned to agent producing the original deflection upon return of the quantity undergoing measurement to the value B_x.

Area $BCDD'_y -$ area $BEDD'_y =$ area $BCDE \asymp$ energy dissipated in the instrument during the cycle $= E_h$.

$K_xL_x =$ the range of values of the quantity measured for a given deflection K_y.

$M_yN_y =$ the range of deflection or indication for the value M_x of the quantity undergoing measurement.

OC and $OE =$ respectively, remanent deflections or sets when quantity undergoing measurement is reduced from $-B_x$ to zero and from $+D_x$ to zero.

OS and $OR =$ respectively, residual values of quantity undergoing measurement when deflection is reduced from $-B_y$ to zero and from $+D_y$ to zero.

Efficiency of resilience, or resiliency of the instrument over the cycle $BDB =$

$$\frac{\text{area } BEDD'_y.}{\text{area } BCDD'_y}$$

If the action of the instrument be without molecular and mechanical friction at a vanishingly small rate of change of x, the two branches of the loop will coincide and the energy returned to the deflecting agent upon completion of the cycle will be equal to that required to produce the deflection, this being the ideal case sometimes nearly approximated in instruments of the most excellent properties. (In purely optical systems the approximation is perfect, so far as is now known.) When this condition obtains, the resiliency becomes unity and the system a conservative or non-dissipative one. Moreover, the "apparent sensitivity," as determined from the slope of either the upward or downward branch of the loop (now reduced to a line), becomes single-valued and equal to the inherent or "virtual" sensitivity; the deflections of the instrument are then perfectly reproducible and independent of its previous operational history.

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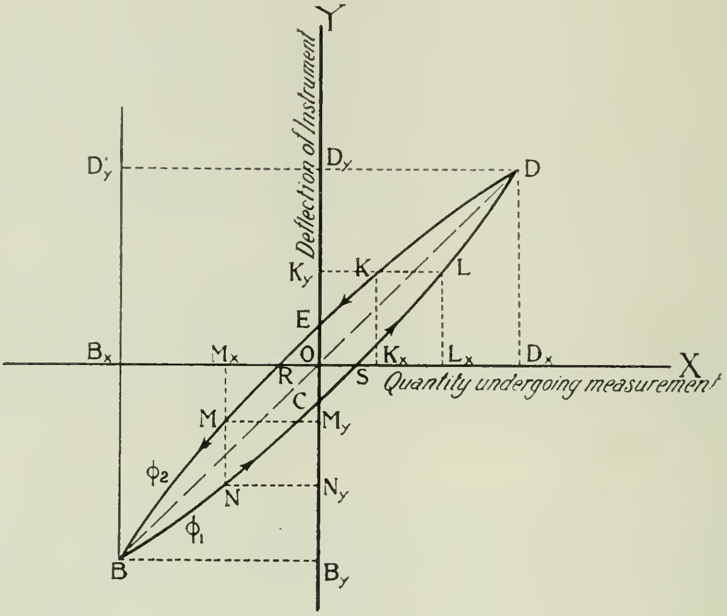
[5] It should be noted that, in addition to the energies discussed in this and the following paragraphs, certain current-using electrical instruments require a continual supply of energy to maintain the deflection, due to the special characteristics of the type of instrument in question. However, this is not true for example of electrostatic instruments.

It may be desirable to consider the actual nature of the energy loss in the instrument, which can be illustrated by a simple example. Consider the case of the familiar pressure gage of the Bourdon tube type. As the pressure in the closed system to which the instrument is connected is gradually increased, a deflection, more or less elastic, takes place in the Bourdon tube, which drives the indicating train and thence the pointer; the deflection of the pointer represents to some scale the energy supplied to the instrument by the source of pressure (aperiodic change of both x and y being assumed throughout the cycle). When the applied pressure is relieved, the deflection reduces to approximately its initial or zero value, while the stored energy is only in part returned to the agency which first supplied it. Clearly, however, as was illustrated in detail in the author's earlier paper, the forces in the gage opposing the applied pressure are at every point somewhat smaller during the period of release of pressure than during the period of its application, the difference obviously representing the

FIG. 2



resultant of the forces of friction (molecular friction in the Bourdon tube, and friction of sliding in the elements of the instrument linkwork). A source of difference in the forces obtaining in the two parts of the cycle, related to and dependent upon the latter of the two causes just mentioned, arises in the change in the moment arms of levers, gears, etc., consequent upon the kinematic change in the relations of the centres of relative motion of journals and bearings, also discussed in the earlier paper. It was there shown that these shifts always act in such a manner as to reduce the restoring forces available within the instrument on the downcoming branch of the calibration curve as compared with those obtaining on the upgoing branch, and so contribute to a separation of the two branches evidenced as a hysteresis loop.

III. EVALUATION OF THE HYSTERESIS LOSS.

Since in every indicating instrument the motion of the indicator through any displacement—whether rotational or translational—implies the existence of a motive force to bring about such displacement, opposed by an equivalent reactive or restoring force, the essential coördinates of a work diagram apparently always exist. When the form of the function connecting the restoring force and the deflection of the indicator has once been determined, the results of the cyclic calibration described above can readily be plotted and measured in units of work dissipated in the instrument over the range of operation under consideration.

In the case of any particular instrument, then, the loss of energy consequent upon imperfect reversibility of the instrument operation can be calculated from the complete calibration curve when certain constants of the instrument are known. In the simple case of an ordinary spring scale, or Jolly balance, the area in dyne-centimetres of the calibration loop obtained by plotting load against deflection of the spring gives directly the energy loss in the cycle of operation under consideration, thus using the notation of Fig. 2:

$$E_h = \int_{B_y}^{D_y} [\phi_1(y) - \phi_2(y)] dy$$

In this case, of course, as in the figure, the *normal* relation between load and indication is sensibly a linear one. In the case of an ammeter,[6] the energy stored in the instrument when a full scale reading is obtained is (*neglecting friction*) equal to the stiffness of the hairspring expressed in torque per unit deflection of the pointer, multiplied by the angle through which the pointer has turned. The displacement factor of the lost-work diagram bears its direct equivalence not to the reading in amperes, but to the actual pointer deflection in units of angle. If the instrument were without friction, either mechanical or molecular, the energy represented by any slow, aperiodic deflection would be precisely equal to the electrical energy taken up from the circuit in producing the deflection, neglecting the energy loss due to the heating effects of current flow. Likewise in returning to a zero reading, the instrument would restore to the circuit, if it remain connected, an amount of energy equal to that applied in producing the deflection. Actually, the excess of energy drawn from the circuit on increasing current is equal to the electrical equivalent of the friction loss for the upgoing branch of the cycle, while the deficiency of electrical energy returned to the circuit on decreasing current is the equivalent of the friction loss for the downcoming branch of the same cycle.

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[6] The following analysis, for which I am indebted to Dr. F. B. Silsbee of the Bureau of Standards, of the energy exchange involved in the deflection of a direct current electrical instrument shows in detail the mechanism of this transfer of energy from the current which is measured, to the measuring instrument: Consider a rectangular coil of n turns, having dimensions $l \times 2r$. A permanent magnet provides a magnetic field of strength H assumed uniform and radial. To compute the sensitivity we have for the side thrust on unit length of wire carrying a current I in a field H, $F = HI$ (1). Hence the torque on the entire coil is $\tau = 2HInlr$ (2). When the coil is at a steady deflection θ, this torque is balanced by the restoring torque of the spring $\tau = K\theta$ (3). Therefore by (3) and (2) the sensitivity $S \equiv \frac{\theta}{I} = \frac{2Hnlr}{K}$ (4).

To compute the energy which must be supplied to the coil electrically to produce the deflection (*i.e.*, the amount over and above I^2Rt required to maintain the deflection) we must compute the back electromotive force produced by the motion of the coil. For a unit length of wire moving with velocity v across a field of strength H, the induced emf is $e = vH$. Since $v = r\frac{d\theta}{dt}$, the total emf in the coil is $E = 2Hr\frac{d\theta}{dt}nl$. The rate at which energy must be supplied to force the current I against this back emf is $EI = 2HInlr\frac{d\theta}{dt}$, and the total energy required to produce the deflection θ is $W = \int EI dt = \int 2HInlr \frac{d\theta}{dt} dt = 2Hnlr \int I d\theta = SK \int I d\theta$ (5). For a gradual increase of current $I = \frac{\theta}{S}$ by (4), and therefore, from (5) $W = \frac{K\theta^2}{2}$ which shows that, neglecting dissipation by friction, all the energy is ultimately stored as potential energy in the spring.

It is interesting to note that if instead of a gradual application of current, a constant current I is *suddenly* applied, eq. 5 gives $W = SKI\theta = K\theta^2$, *i.e.*, twice the former value. The additional energy is of course dissipated in the damping of the instrument before the coil settles down in the deflected position.

As in the case of the ammeter, a hysteresis loop properly expressing the energy dissipation may often be obtained by referring the deflections not to the actual reading scale of the instrument, but to a uniformly divided scale, substituted for the purpose of the determination, for that provided on the instrument. Generally speaking, this will give the desired result, since, although the relation between the quantity which the instrument is to measure and the scale of graduations expressing that quantity may not be linear, that obtaining between the resisting force or torque and the deflections themselves in units of translation or rotation, usually is linear on account of the common practice of using, for the sake of simplicity, resistor elements having a closely linear stress-strain relation, such as hairsprings, torsion wires, plate springs or diaphragms, helical extension springs, or pendulum elements undergoing small deflections (such as the beam of a balance), etc. Thus, even in a centrifugal flyball or inclined-ring tachometer in which the relation between rotational speed and deflecting torque is very likely far from a linear one, the relation between torque and angular deflection of the pointer will be linear if the resisting torque is centered in one spring at the indicator spindle. If, as is often the case in tachometers, the resisting force is localized in two places, separated by links not having linear velocity ratios, the total resisting torque and the proportions of the total resisting torque assumed by the indicator hairspring and the governor spring, respectively, may differ for every configuration of the system. In such cases the lost work may whenever necessary be evaluated by kinematic analysis of the mechanism discussed on the following page.

Similarly, in the case of a vapor-pressure thermometer, the graduations are distinctly non-uniform on account of the nonlinear relation between temperature and vapor-pressure, yet the *vapor pressure-angular deflection* relation will in the usual designs be found to be a linear one. To set up a linear relationship between deflection and temperature in such an instrument has not in the past been deemed practicable on account of the kinematic complexity which the obtaining of such a relation would involve when conventional linkworks consisting of lower pairs and gears are utilized. In such an instrument, then, the required work diagram would be obtained by plotting not temperature against reading, but rather vapor pressure corresponding to temperature, against angular deflection of the indicator, thus affording the requisite coördinates of force and displacement. To generalize on this matter is somewhat difficult on account of the unavoidable complications introduced by the diversity of types and mechanical construction of instruments. It is believed that when due consideration is given the mechanism of the particular instrument, no difficulty will be had in any given case in arriving at the proper basis for the work diagram.

As a useful example in this connection may be mentioned an instrument in very wide use, namely, the steam engine indicator, in which the linkwork usually used to connect the piston and the recording pencil affords only an approximately straight-line relation between the displacement of the indicator piston and that of the recording pencil, hence between the load on the indicator spring and the displacement of the recording pencil. To arrive at a precise expression for the displacement at the recording pencil for any given displacement of the indicator piston, an exact determination of the approximation referred to is required and will, of course, involve no great difficulty, being obtainable with ease graphically when analytical methods are arduous. In this particular case the error is not great, and in fact must not be great if the autographic diagrams drawn by the instrument in actual use are to be evaluated without the necessity of continually applying complicated corrections. It is interesting to note that in the case of this instrument, the obtaining of an exactly linear relation between the displacements of piston and pencil has always been associated with the use of higher pairs, such as a cam-plate and roller, which as carried out in existing forms of steam engine indicators has undoubtely involved a marked increase in the friction losses.

Setting up the proper coördinate screen to obtain a calibration loop capable of expression by direct planimetry, in units of work lost in the cycle, involves then only a knowledge of the stress-strain or force-displacement relation of the elements affording the resisting agency of the instrument and of the kinematic function expressing the displacement or "velocity" ratios of the elements of the linkwork.

IV. THE APPLICATION OF THE HYSTERESIS DETERMINATION.

I. THE CYCLIC STATE.

(*a*) *Aperiodic Change in the Variables an Essential.*—In the study of hysteresis phenomena of instruments it was noted that constancy in the outline and area of the hysteresis loop required that the change of values around the cycle between extreme points of reversal be always in the same direction. By implication, this requires that the motion of the indicator or pointer be aperiodic[7] or, practically speaking, slow, since if the rest-point be attained only after oscillation, the parts must necessarily have traversed a retrograde deflection. In fulfillment of the same requirement, the determination of the hysteresis of an instrument is to be carried out in the absence of all jarring and vibration.

This fact, as well as the necessity of getting the specimen into the cyclic state, is apparently well known in the case of magnetic hysteresis, and was thus noted in Hallo and Land's "Electrische und Magnetische Messungen and Messinstrumente" with regard to the recording of the magnetic hysteresis loop: "Alteration of field in the wrong [reverse] direction makes the whole series of observations useless."

It would appear from the magnetic analogue, and more definitely from experiments which the author has now in progress relative to this matter, that a reversal between the chosen end-points always has the effect of cutting in on the normal loop[8] that would otherwise be obtained.

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[7] It is to be noted that causing the indicator to approach its rest-point with a slow, aperiodic motion has the effect of eliminating as disturbing factors: (1) damping resistances afforded by fluid friction or friction having similar characteristics; (2) kinetic effects of mechanical friction, such as are directly or indirectly occasioned by oscillatory motion about a shifting rest-point, such that the rest-point becomes indeterminate in dynamic operation of the instrument; (3) time lag engendered by the inertia of the mechanism, a lag of rate of deflection behind the rate of change of the independent variable, depending primarily upon the rate of that change. All indicating instruments have a period of oscillation determined by the magnitude of the restoring force at the particular reading and by the magnitude and nature of coupling of the masses involved, so that even apart from the double-valued form of the aperiodically determined hysteresis function, the instrument indication at any instant is not uniquely determined, when the indicator is in motion, by the instantaneous value of the independent variable.

The necessity for the continuous aperiodic change of the variables will be clear when the general nature of hysteretic cycles is recalled. The coördinates of any point on such a cycle are a function not only of the value of the independent variable then obtaining, but also of the previous cyclic history.

(*b*) *Regularization Antecedent to Calibration.*—It necessarily follows, moreover, that the specimen under consideration, whether it be a magnetic body, a structural element under stress, or an instrument undergoing calibration, must first be *accustomed* to the cycle under investigation by being " stressed " and relieved a number of times over the same cycle.[9] By this procedure the previous and unknown history is, so to speak, obliterated and the mechanism is regularized in that the parts, whether molecules or finite mechanical elements, are set into stable and more or less perfectly reproducible relationships,[10] which, however, are immediately disturbed and disestablished upon reversal of the " stress " before the chosen end-point is reached.

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[8] As it is hoped to demonstrate in detail in a later paper for which the experimental work is now practically completed, this normal loop is a maximum of all obtainable for any two turning points lying between the chosen extreme turning points, and, moreover, completely encloses and circumscribes all such minor loops, a circumstance which, if definitely demonstrable, involves conclusions that will be of great value in exact utilization of instruments as well as in their testing, and will, for example, open the way to precise autographic determination of the hysteresis cycle of an instrument without anomalous distortion of the results by the hysteresis of the autographic recording apparatus itself.

[9] The cyclic state with respect to stress strain loops for steel under tensile and compressive stress is discussed in some detail in " Stress-Strain Loops for Steel in the Cyclic State," by J. H. Smith and G. A. Wedgwood, *Journal of the Iron and Steel Institute,* 1915, xci, p. 365.

[10] So far as experience and analysis are now available to guide us, the cyclic state can be set up in all indicating instruments except those in the following two categories, in both of which special treatment is necessary: (*a*) those in which a sensible time effect intervenes, or in which transient phenomena are of importance even at rates of change of indication which are markedly slow. (The aneroid barometer, it is believed, is such an instrument.) (*b*) those in which an uncompensated backlash exists, in which circumstance the indicator is definitely unconstrained (in the kinematic sense) for some or all configurations of the mechanism. This case, which is a very interesting one, will be discussed in a later paper.

2. THE INDICATIONS OF AREA AND FORM OF THE HYSTERESIS LOOP.

It will readily be seen that of two instruments operating over the same range of indication, that is the better which has the smaller mean hysteresis per cycle, except for the following factor, which is practically of secondary importance, and will not fail of being noted in the calibration, *viz.,* the shape of the hysteresis loop—of exactly analogous import to the form factor in statistical distributions. In the case of one instrument, a regular, smoothly outlined hysteresis loop may be obtained, with a fairly large displacement between its branches; in another the branches of the loop may in general tend to lie much closer together, and yet at some portion of one or both branches an abnormal divergence will appear, due, let us say, to binding or sticking of the mechanism, as may easily occur from local bad fitting or misalignment of parts. While, even with this local divergence in the two branches of the hysteresis loop, the second instrument may exhibit a notably smaller total energy dissipation—it may be the less serviceable of the two, since under certain conditions or accidents of use the high local variance may be of serious import. Clearly, then, we must define both aggregate (or mean) energy loss, as in dyne-centimeters per unit change of the independent variable, and *distribution* of energy loss. The latter may perhaps best be expressed by such a term as *maximum energy dissipation,* again in dyne-centimetres, per unit change of the independent variable. Such a term, then, fills somewhat the same function as does *extreme deviation from the mean* in characterization of statistical distributions.

3. EFFECT OF VIBRATORY TREATMENT.

When vibration treatment is employed to minimize frictional lag in instruments, the portion of the hysteresis loop which is effaced thereby represents in part the contribution of energy from the vibrating agent that has been made available in the instrument. The amount of the diminution of the hysteresis loop occasioned by properly applied vibration treatment is nothing less than astonishing, and in some cases where the instrument is sufficiently rugged to withstand vibration of considerable amplitude and energy the variance can by such treatment be reduced to a few per cent. of its value in the untapped condition. The writer would hazard the suggestion that certain types of instruments might well be provided with in-built mechanical or electrical vibrators, which would assure both the proper orientation and the required amplitude of vibration.[11] Reasoning from analogy, there seems to be cause to believe that vibration treatment will also reduce the hysteresis effects arising from imperfect elasticity or other molecular causes or even irreversible time effects or drifts. Certainly it is true that in the case of magnetic and dielectric hysteresis and dielectric time lag, each of the effects is modified by jarring, in a very definitely measurable amount and rate, as reported by Ewing and Kohlrausch for magnetism and electric charge, respectively. The effect of vibration treatment on plastic lag is an interesting study whose further elucidation is to be hoped for.

4. THE OCCURRENCE AND CAUSES OF HYSTERETIC LOSSES IN LIQUID-COLUMN INSTRUMENTS.

Experimental data which would permit of a satisfactory analysis of the energy losses associated with the motion of a liquid in an inclined or vertical tube, such as occur in the case of barometers and other manometers, are unfortunately lacking, and it is hopeless to discuss this matter in any detail in the present state of our knowledge of the subject. It seems certain that in the displacement of a liquid meniscus or of the capillary surface about an emergent rod, a transfer of energies takes place apart from that involved in the velocity of the movement. How this depends upon the purity of the materials at the boundaries and upon the wetting or non-wetting of the surface of the tube has never been analyzed, so far as the writer knows. In the case of the spirit-level, the circumstances seem especially to favor a minimum of intransient irreversibility, since the condition of the system as regards the wetting of the surface of the tube and the vapor tension in the entrained bubble, etc., may be expected to undergo the very minimum of alteration during the assuming of a new rest-point by the bubble. Consultation with experts in the use of astronomical and geodetic instruments has elicited only the information that it is considered necessary to tap the tube in taking observations in order to obtain the most reproducible results, suggesting that a sensible amount of lag was considered to intervene, although exact studies of such lag and information as to its amount are lacking.

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[11] Since writing the above, the author has come upon unexpected instances of actual utilization of the principle above suggested of applying to an instrument definite mechanical means for diminishing lag by a graduated and directed vibration—possibly in William Thomson's siphon recorder for cable telegraphy and certainly in the Cuttriss modification of that instrument. In the latter, persistent mechanical vibration of the recording pen or siphon to which is affixed a minute bit of iron, is produced by pulsations of flux in a subjacent magnetic field. The effect is to keep the siphon in continual vibration into and out of contact with the paper upon which it registers, with a fairly high periodicity; while drawing a graph that is practically continuous, the pen is, nevertheless, intermittently relieved of all constraint due to mechanical friction, thus performing substantially as well, as regards freedom from lag, as would a freely suspended galvanometer element. It is understood that a similar principle is incidentally applied in the telautograph, a slight vibratory motion of the writing pen being maintained by use of superposed harmonics on the sending current with the effect of reducing the frictional lag originating in the linkwork and in the contact between the recording pen and the paper. The author's attention has been directed also to a certain French-made watthour meter, in which is incorporated a small auxiliary motor whose function is to oscillate the brushes continually through a small angle, thereby greatly diminishing the effects of brush friction.

Another observer experienced in the use of the astronomical level has stated that not only does perceptible lag probably occur, but that he has frequently noted a step-by-step advance of the bubble, very suggestive of static frictional resistance, in that the bubble will seem to have stopped completely and will then advance a short interval, repeating this possibly a second time in a manner not dissimilar to that familiar in more common and less delicate mechanical instruments.[12] This observation, of course, if it be correctly recorded, represents one sort of manifestation of passivity effects, discussed in greater detail in the earlier paper.

Inquiry was made of the Coast and Geodetic Survey with regard to the spirit-levels used on precision surveying instruments, and information was received that the existence of lag in level-tubes is realized in that service, but that its magnitude has not been measured. Moreover, the statement was made that tapping of the instrument to reduce the effect of the lag was impracticable for their purposes, on account of the possibility of thus disturbing the constancy of the relation between the axis of the bubble and the line of sight of the instrument. However, the method of observation used was such that by reversal of the level-tube the bubble was brought to rest from opposite directions (with reference to space), so that if only the lag remained constant, its effect on the accuracy of the observations would be practically eliminated.

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[12] This intermittent motion of a fluid element, striking and anomalous though it may seem, has been observed by Gore ("On the Capillary Electroscope," Proc. Royal Society, 1879, Vol. 30, page 32), and discussed in some detail in the above paper. He ascribes it, in the case of the capillary electrometer, "to a sudden increase of mechanical resistance, usually caused by unequal adhesion of the mercury to different parts of the tube, but sometimes by a minute trace of solid substance in the tube. With a very feeble current this adhesion shows itself in several ways, usually by a more or less sudden retardation or stoppage of the motion of the mercurial column, by a delay in its commencement of motion, or by its non-movement." By adopting certain changes and precautions he found, he continues, "that the mercurial column, instead of moving from point to point with a jerk and stopping suddenly, moved with a gradually diminishing speed until it stopped."

Experimental information in regard to intransient irreversibility in the case of level-tubes would be of definite value in many lines of engineering and physical work.

In general, the tendency to assume that instruments employing a liquid meniscus are sensibly without variance is not a safe one, for it is well known that a marked hysteresis exists even in the case of hydrometers used with all due precautions with respect to cleanliness of surface and constancy of temperature. For example, the section of the Bureau of Standards dealing with calibration of volumetric glassware has reported that in sensitive hydrometers having a slender stem and large bulb, graduated to .0001 (specific gravity) over a range of about .0150, the variance may amount to 2 or 3 divisions under the best laboratory conditions, while in commercial use it may easily be much greater. Even this variation, moreover, would probably be increased were the instrument required to assume its final reading without oscillation. The same type of variance has been noted in differential, two-liquid manometers, when they are so adjusted as to be very sensitive.

Assuming as a specific example the ordinary liquid column manometer, it is clear that as the meniscus travels along the tube a change in the shape and area of the free surface must take place. This action may account for the imperfect reversibility of the calibration of such an instrument in one or both of the following ways: The change in the meniscus will certainly involve the occurrence of the effect well known in inverse form in the capillary electrometer, producing a change in the electric potential. Moreover, William Thomson determined the thermodynamic transfer following such changes in the configuration of a free liquid surface, such that to keep the temperature constant when the area of the surface increases by unity, an amount of heat must be supplied which is dynamically equivalent to the product of the absolute temperature into the decrement of surface tension per degree of temperature, this being known as the latent heat of surface extension.

The significance of these two phenomena in relation to the present discussion lies in the fact that change in the one case of electrical charge, and in the other of temperature, would account in some measure for the irreversibility which has been noted in liquid column instruments, in that either change would in itself occasion a determinate alteration of the shape and tension of the meniscus. Considerable research would be required to evaluate these phenomena as they relate to instrumental hysteresis. It may even be that increasing the heat or electrical capacity and reducing the insulation of a liquid column instrument would notably enhance the reproducibility of its readings.

Apart from the possible causes above suggested, undoubtedly dirty, or in the case of mercury, oxide-coated liquid surfaces play an important rôle in the hysteresis loss of liquid manometers and hydrometers. Such a result is of course easily to be explained on the basis of irregularities in the value of the surface tension, irreversible on account of their accidental nature, and of a sort of solid, or better perhaps, granular friction manifesting itself whether at the bounding surfaces or in the mass of the liquid.[13]

5. EQUIVALENCE OF RANGE OF OPERATION A REQUISITE FOR COMPARABILITY OF RESULTS.

Reliable quantitative comparison of instrument performances by the use of the resiliencies computed on the basis of their hysteresis loops will require that the range of reading or operation for the instruments compared be the same or that the ranges used be reduced to the same basis by computation based upon a knowledge of the function connecting the range of operation with the area of the hysteresis loop. For example, in comparing a pressure gage of a capacity of 200 pounds/in^2 with one of 300 pounds/in^2, either the observations must be taken over a range common to both instruments, as for example from 0 to 200 pounds/in^2, in which case a portion of the range of graduation of one is necessarily discarded—or a factor must be found by which observations over the full range of the respective instruments can be reduced to an equivalent basis.

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[13] Reverting to the case of the capillary electrometer, there is no reason to suppose that Gore's modifications *totally* eliminated irreversible lag in the instrument, and, in fact, the contrary is undoubtedly the case, as is indicated by the evidence of the astronomical level where all practicable perfection of tube and purity of liquid are closely approximated, and in which, nevertheless, the existence of finite passivity seems established beyond question. Some aspects of this question seem to lead inescapably to the postulate that actual liquids are not sensibly perfect in the sense of the definition by which liquids are customarily discriminated from solids as being substances capable of persistent deformation under an infinitesimal value of shear, or in the terms of Maxwell's definition, as substances which, if the smallest force be long enough

Some information is available with respect to a limited phase of this subject, from the researches of Rowett,[14] who made a valuable study of torsional hysteresis. According to Rowett, the energy dissipated in torsional hysteresis of steel is proportional very exactly to the third power of the range of stress to which the member is subjected. He noted also that the loss was sensibly independent of the frequency [which is equivalent to a statement that the hysteresis is without time lag]. These results will, of course, apply rigidly only to that portion of instrumental hysteresis contributed by torsionally stressed elastic elements such as torsion bar springs, filar torsion suspensions, helical springs under axial loading, etc., and on that account computation of hysteresis loops of most instruments to equivalency of range, when actually taken over diverse ranges, is not generally practicable except by experiment and extrapolation on the class of instruments in question.

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applied, will undergo a constantly increasing change of form. It may even be that complete liquidity (in the sense of perfect accordance with the above definitions of the liquid state) is not practically attained, even in the absence of cognizable dirtiness and granularity, and that there is no definite or sharp line of demarcation between existing viscous liquids and plastic solids. It is fitting to note that if the above surmise is correct, it is probably without present practical importance except in the case of measuring instruments of precise character, wherein alone the deviation from complete liquidity is observable, if it exists. The minuteness of the quantum under consideration is suggested when it is recalled that the intrinsic lag referred to in the case of the astronomical level becomes noteworthy only in measurements of angle tending toward a precision of a part in a million or more.

[14] F. E. Rowett, "Elastic Hysteresis in Steel," Royal Society Proceedings, Vol. 89A, p. 528, Dec., 1913.

V. PRACTICAL UTILITY OF THE METHOD—MEANS FOR IMPROVING INSTRUMENT RESILIENCY.

The hysteresis loop in instrument calibration, then, affords as important and necessary information as does the indicator diagram in engine testing. It permits the ready determination of the mechanical performance or "efficiency" of the instrument, referred to an ideal instrument completely devoid of friction of all kinds. The mean efficiency of performance of an indicating instrument can then be rated in terms of the completeness of its resilience, while a definite range of indication for any given value of the quantity measured, and a range of values of the quantity measured for any given indication can be directly scaled from the hysteresis diagram.

The practical application of the hysteresis determination in instrument testing may be regarded somewhat in the following way: In the ordinary method of calibration the errors are commonly determined at various points on the instrument scale, for change in one direction only of the quantity which the instrument is designed to measure, the instrument often being tapped at the time of reading in order to minimize the hysteresis effects. This method affords a means of selection between members of a group of instruments all of one type of design and construction, when substantial equality of frictional errors is assumed for all members of the group.

On the other hand, the determination of instrumental hysteresis under a condition of slow aperiodic change of indication and in the absence of jarring and vibration, enables one to differentiate between instruments of different types, so making possible the choice of that type which is *capable* of the best aggregate mechanical performance. With regard to the method first described, it may be said that the absolute errors of indication, expressed if necessary by a mean or average value, represent the result of the adjustments to which the instrument has been subjected; and, within limits, the mean of such errors at any point of the scale is alterable at will by changes in *adjustment* which are or can be provided for in the mechanical details of construction. Such changes in adjustment include alteration of the active length and strength of a restoring spring, change in the length or angularity of some link of the mechanism, alteration of the spacing of graduations or modification of the contour of a cam. The variance errors, on the contrary, which are not eliminable by any of the above operations, afford a reliable criterion of the *characteristics of the type* of instrument, representing within the limits of course of individual variation, not so much the performance of a particular instrument as that of the class to which a given operating principle or mechanism pertains.

To alter the variance of an instrument we change not the adjustment, but the operating principle, the design of mechanical details, or the quality of the workmanship on the mechanism (as distinguished from the quality of workmanship evidenced in the carefulness and accuracy of adjustment). For example, reduction of the amount of relative movement of coacting parts will reduce the amount of the variance, other things being equal, since the displacement factor in the work equation is thereby reduced. Similarly, increase of the forces available to cause and resist respectively the motion of the instrument mechanism, provided that the frictional resistances do not rise in the same proportion, is efficacious in diminishing variance. For example, in a diaphragm pressure gage this end will be attained without change of the operating range by increasing the effective area of the diaphragm, if at the same time the reactive force is correspondingly increased. In an automatic weighing scale we attain the same end by reducing the leverage ratio, so that the force available to move the indicating train is increased in inverse proportion. By such changes, if, as is usual, the friction does not increase as rapidly as do the available motive and restoring forces, we accomplish a diminution of the proportionate effect of friction and improve the resiliency of the instrument. Variance may likewise be reduced by improving the fit and finish of coacting parts, as the journals and bearings, or by replacing a part having relatively high frictional moment by one having less, as in substituting a ball bearing or conical pivot for an ordinary cylindrical bearing.

It is to be noted that changes in adjustment intended to decrease errors of calibration will in general affect the variance, but only as an effect of smaller order. The adjustment may change the magnification or " velocity ratio " of the instrument and thereby increase or diminish the work of friction on account of the greater or less relative motion of the coacting parts for a given range of the independent variable. For example, an increase in the magnification of a pressure gauge intended to bring the indicator up to proper coincidence at the extremes of the graduated scale, effected by changing the working length of the adjustable link, will slightly increase the total friction loss, inasmuch as it involves a greater relative motion of the driving gear and indicator pinion.

Attention may be called to the fact that in choosing the particular form of turning pair to be used in an instrument, we are led normally not by considerations of sensitiveness, but of responsiveness—that is, freedom from the passivity of operation attendant upon the presence of friction; or, in a more general sense, we seek a minimum of hysteresis loss in a cycle of operation of the instrument. To be sure the fact that the hysteresis loss actually measures the "uncertainty" or "unreliability" of the indications of an instrument, in so far as this property is related to the mechanical construction, has hitherto failed of recognition; but it was of course perceived that this "unreliability" had its origin in frictional resistances of one kind or another.

It is the relatively perfect freedom from friction in the torsion suspension which has brought about its wide adoption in precise measuring instruments of great variety, together with the fact that in one element it comprises two essentials: the support for the rotation of the deflected element, and the means for resisting that rotation according to a definite and closely linear law. Thus it is that such a suspension, combining as it does in the same substance the motion-constraining and force-resisting elements, makes for minimum variance and passivity, and it is this property and not its "sensitiveness" which gives the torsion suspension its well-known advantage. The flexural suspension which has been employed in micro-balances and in precise mechanical length-measuring apparatus, also affords the combination of a load-supporting and force-resisting element, with the limitation that its angular deflection is practically required to be less in amount than in the case of the torsion suspension.

In making inquiries to determine what, if any, systematic utilization has been made of variance determinations in actual testing of instruments, one interesting approximation to this method of test was met with in factory practice. It was found that sometimes in order to arrive at an estimate of the friction in automatic weighing scales, a load of, say, one-half the rated capacity was placed upon the platform, and the pointer allowed under suitable damping gradually to approach its reading. The final reading attained being noted, additional load up to the rated capacity was applied, and this latter increment then as gradually removed. The reading at half load again being noted, the difference between the two readings at this same load afforded a measure of the effect of friction at one region of the graduations. When the test load is equal to half the capacity of the scale the maximum vertical width of the hysteresis loop is thus approximately determined.[15]

VI. SUMMARY.

This paper deals particularly with those instruments of the index-and-scale and value-controlling types of the class of non-integrating instruments, as distinguished from integrating instruments and those used for comparison purposes strictly. Independent corroboration is adduced regarding the general characteristics of the hysteresis phenomena discussed in the author's earlier paper on the variance of measuring instruments.

It is shown that the area of the hysteresis loop obtained on complete cyclic calibration is a measure of the energy dissipated in the operation of the instrument and that the smallness of the area of this loop, which may be used as a factor in a function exactly analogous to the resiliency in the case of other quasi-elastic bodies, is a measure of the excellence of the instrument as regards the reproducibility or invariance of its indications, so far as concerns mechanical sources of variation. The specific properties of the hysteresis loop are set down analytically and the physical nature and causes of the imperfect resilience of instruments are discussed in detail.

Since the motion of an index or pointer through a displacement implies the existence of a motive force to bring about the deflection, in the presence of an equivalent reactive or restoring force opposing it, the essentials of a work diagram apparently always exist in the results of a properly performed cyclic calibration. Indications are given of the methods to be followed in the process of reducing the results of the calibration to such form that the loop obtained correctly represents energy dissipation during a cycle, typifying an integral of the form

$$\int_{B_y}^{D_y} [\varphi_1 (y) - \varphi_2 (y)]\, dy$$

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[15] This information is due to the courtesy of Mr. H. O. Hem, consulting engineer of the Toledo Scale Company.

when B_y and D_y are the projections of the extremities B and D of the loop on the axis of deflection or reading.

The restrictions which surround the carrying out of cyclic calibrations in a manner calculated to obtain results of the character required are discussed, including the requirements of slow, aperiodic change of the variables, unreversed between the chosen extreme turning points, and accomplished in the absence of jarring or vibration. Attention is directed to the necessity of accustoming the instrument to the particular cycle over which it is to be calibrated, to the end of regularizing its performance.

Both the form and area of the hysteresis loop should be observed, in order to arrive at regional as well as aggregate effects of the causes producing the variance. The amount and scope of the effects of vibratory treatment in modifying and diminishing the causes of lag are indicated.

The possible causes of the lag known to exist in the case of instruments using a surface of discontinuity between fluids as the indicating element are discussed, and it is shown that known phenomena perhaps hitherto unrecognized in their relation to instrument design and calibration may account for the variancy noted. Detailed experimental consideration of these factors is hoped for.

Comparison of instrument performances on the basis of the hysteresis loss requires equivalence of the ranges of operation, or possibly reduction of the results on the basis of information not yet available in a form capable of general application.

The resiliency determination opens up a field for type-testing and selection of instruments on a basis quite discrete from that pertaining to the ordinary methods of calibration, in that the former permits selection between types of instruments rather than between individuals, making clearly discriminable the differences between the characteristics of given operating principles, designs of mechanical details, or qualities of workmanship. The more general methods of diminishing variance educible from the foregoing considerations are indicated.[16]

Washington, D. C., November 9, 1918.

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[16] Since the above paper went to press, a portion of the experimental work referred to in footnote 8 has been given brief publication: *Journal of the Washington Academy of Sciences*, Jan. 19, 1919, vol. 9, No. 2, p. 38. Regarding footnote 10, section (*a*), see "Experimental Elasticity," G. F. C. Searle, Cambridge, 1908, where the mode of setting up the cyclic state in the case of phenomena involving sensible time effects is explained and illustrated.

The Industrial Chemist. A. HENWOOD. (*Drug and Chemical Markets,* vol. 5, No. 7, p. 5, October 23, 1918.)—The mathematicians have a phrase which applies admirably to all problems with which we may be confronted. It is their custom to speak of a set of conditions as "necessary and sufficient" for the solution of a problem. In the course of training which we commonly give our prospective chemists, we have undoubtedly recognized and applied many necessary conditions, but it is fairly open to question whether the conditions that have been recognized and applied are sufficient. The necessary and sufficient elements of a course of training can only be determined by a careful and accurate analysis of the environment in which the individual is to be placed. Too often the content of a course of training has been determined from preconceived requirements dictated by existent courses or by previous experience in fields none too closely related to the one under consideration. The result is that many necessary elements have been overlooked and many unnecessary elements have been incorporated which have consumed the student's time without developing in him the type of competency desired.

The graduate of the average chemical course, when he enters an industrial organization, finds himself in an environment utterly different from anything he has before experienced. He has certain elements of training which give him some degree of usefulness, but he lacks many which he must acquire by the painful and costly process of trial and error. His chemical training has not considered the limitations imposed by engineering conditions, and his engineering training has not been sufficiently influenced by chemical considerations which profoundly modify ordinary practice.

On the other hand, there are other elements not having directly to do with the transformation of substances or with energy which nevertheless are of first importance in the training of the industrial chemist. Moreover, it is just these subjects that are treated as of secondary importance by both student and faculty. One of the first requisites in an industrial organization is that its parts coördinate accurately. It is astonishing how purely technical subjects lose the supreme position they occupied in the academic world, and how problems of human relationship assume the position of importance. This can be easily verified by reference to the experience of any technically trained man who has entered the industrial field.

In the past, there has been a lack of coöperation between the school and the industrial organization; at present, this condition is undoubtedly passing away; in the future, it may be hoped that they will work hand in hand, the one being a continuation and fulfillment of the other. The best course of training for the industrial chemist cannot be proposed by any one man or by one group of men. It is a problem which will require and is worthy of the best and most active efforts of industrialists and educators. It would seem entirely possible for such a group to state the conditions "necessary and sufficient" for the training of an industrial chemist.

WINDMILLS, PICTURESQUE AND HISTORIC: THE MOTORS OF THE PAST.*

BY

F. H. SHELTON.

Philadelphia.
Member of the Institute.

THE pessimist says that man is a lazy animal and that he invents machines to save himself work. The optimist, that man is an industrious creature who invents machines that he may accomplish the more. Whichever doctrine is right, there is but little question that of all the ingenious contrivances evolved by man none is more picturesque, of more historic interest nor of greater usefulness in its day than the old-fashioned windmill, the world's principal motor for some eight hundred years. And " motor " is the viewpoint to take of this old piece of mechanism, for just as the later devices of steam, electricity or gasoline are for the purposes of making power for the needs of man, so was this old appliance for the prime purpose of securing power from the wind, and by thus harnessing that most widely distributed of Nature's forces, of enabling the accomplishment of work far beyond the limits of manual power.

The steam engine came into use in the early part of the nineteenth century. By 1825 most of the principal English cities had it in use. Before that period, and dating back to remote ages, the only sources of power—other than man or bullocks, etc.—were the two great forces of wind and water. But only countries of waterways and varying levels afforded waterfalls; while the wind was universal. Therefore, while water wheels were in use in parallel periods with the oldest of windmills, in number they were infinitely less, so that one can properly say that the world's motor for some eight centuries was the old-time windmill. These eight centuries are from about 1000 to 1825, when, with the advent of Watt's invention, the zenith of windmill design and use had been attained. After that date they so declined that in fifty years not only had new construction ceased, but the old structures in very large measure had fallen into decay and abandonment. It is evident from the above that an account of this old, picturesque, historic and effective tool of mankind should have some interest, both from the standpoint of engineering and that of sentiment; and it is believed that what follows will give the essential facts relating to it. It may be proper to say here that what is related applies entirely to the old-style windmill, and in no measure whatever to the modern American type of windmill, which, while cheap, effective and useful, is nevertheless a prosaic, galvanized iron, squeaky thing, of which happily the larger proportion of the millions annually made is exported out of our country!

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* Presented at a meeting of the Mechanical and Engineering Section, held Thursday, March 14, 1918.

While the antiquity of windmills is traced by some back to the Romans there is really nothing very definitely known of their existence before the period of the Crusaders. They were said to have been brought into central Europe in that period from the Far East; though this is open to question. Practically their origin is lost in antiquity, and we only know that they appear in the earliest records as existent in some form or other.

But by 1200 they were well established. The first English windmill is of 1191. There are numerous records of them in the thirteenth century. There is a brass tablet of 1349 at Lynn church, with a windmill graven on it. In old stained glass of the early churches windmills are shown in some of the landscapes; as at Great Greenford and Fairfield. In a view, "London in the time of the Tudors" (1560), windmills are seen; and Great Windmill Street commemorates to this day the location of one in the past in that city. Elsewhere it was the same. Rembrandt, of the early part of the seventeenth century, shows such mills in some of his pictures; and in the early prints and views of France, Germany and other countries is abundant evidence of the use of these old, useful machines, in various forms, places and ways.

What was standard in the old world was naturally brought into the new, and so we find in America, concurrent with the colonies and settlements of the early days, the introduction and use of windmills. The Dutch in New Amsterdam, in 1625 and later; the Swedes on the Delaware, in 1643; the English in Rhode Island, in 1665 and 1675, and Boston, in 1660; and on the Carolina coast—all had their mills, as shown by early records, maps and views. And these mills were logically the types used by the respective settlers, according to the district from which they had come. For instance, the old mill in Somerville, Mass., built in 1710 by Jean Mallet, a French Huguenot, is of the pure French type; as were those near Detroit, by the followers of the fortunes of Cadillac; while those in Talbot, Kent and Dorset counties, Maryland, reflected the clear English design of the old country. The same applies to the numerous ones erected in the colonial days of 1725 to 1775, in Easthampton, Bridgehampton, etc., on Long Island; at various points on Cape Cod; at Nantucket (1746); in numerous instances on Newport Island, Rhode Island, etc. A notable one of this type and period was that on Windmill Island in the Delaware River, shown in an old view, "An east prospect of the City of Philadelphia," 1746. All these reflected the English design of the emigrant settlers, bringing with them and promptly setting up and using the motors or machinery of the mother country.

There are two forms into which these old mills can be grouped, *viz.*, vertical and horizontal. By that is meant the relative position of the wheel and shaft. The vertical is that form in which the wheel is vertical, mounted on a shaft which is horizontal or nearly so. This is the form almost universal, for while various instances of the other have been tried, scarcely one in a thousand has been used compared with the vertical type. The reason for this is that in the vertical form of wheel, its face directly confronting the wind, all vanes are acted upon at once, and there is not only the greatest resulting power, but the greatest simplicity of construction and of operation and handling. The horizontal wheel, on the other hand, occupying a horizontal zone and attached to a shaft that is vertical, like the usual small water turbine, in position (but not in the fluid impact) receives the wind impact upon only some of the vanes at a time—not the whole circumference—with less proportional power and greater complexity of construction. So secondary has been the use of this style of windmill that consideration of it is negligible.

From the design standpoint, windmills involve four essential component parts:

(*a*) A tower, or means of support for the moving wheel and mechanism.

(*b*) A revolving wheel that receives the impact of the wind, converting it into power.

(*c*) Some means of turning the wheel, to follow the shifting of the wind; and,

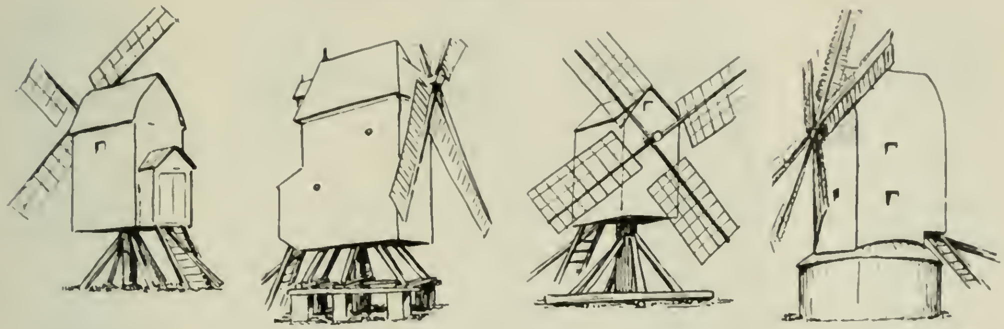
(*d*) The driven machinery.

(*A*) *The Towers or Supports.*—The support in the earliest form of mill was merely a post, made of a suitable log or tree trunk—sometimes 30 inches thick—upon which the entire structure was carried or hung and pivoted, so that it could turn freely to the wind. This was the original type—the old "post-mill," appearing in the earliest known prints and records, and alone used until about 1650. At that time the "tower mill" was developed, and this, of larger possibilities, soon resulted in great structures of that style being built, that generally replaced and threw far into the shade the earlier and simple post form.

The towers of this latter form of old windmill were made of every conceivable or possible form and material. Straight or cylindrical; tapering or cone shaped; octagonal or multi-sided; even bottle shaped, like a mammoth milk bottle of the present time. Again, on open arches, as in two notable structures later referred to—anything to carry the overhead work, according to the fancy or purse or conditions governing the builder. Of brick or stone or wood; slate, shingle or thatch covered, in height these towers ranged from 25 to 100 feet. The largest ever built was at Great Yarmouth, England, 11 stories high, and over 100 feet, exclusive of the great vanes. The great Dutch grist mills were however, a close second in height, and with a base of some 35 feet and a top width of 16 feet were massive structures indeed. These tall structures were divided by various floor levels, the lower rooms thus formed containing the mill-stones or saw or other driven machinery, while the upper ones were used for living quarters or storage. The structure of the smaller post mills, however, being suspended on the centre posts, was never of stone or brick, but wholly of wood, and these rotating or movable buildings ranged in size from about 10 by 12 feet to 16 by 24 feet in the larger ones, and up to two stories in height.

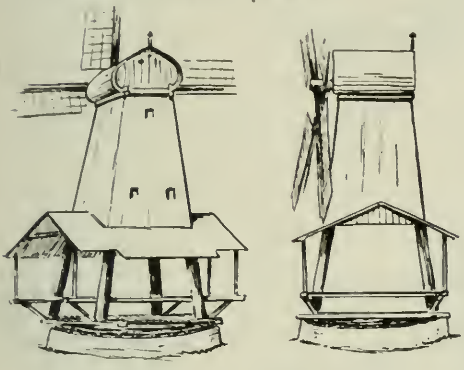
At the top of the mills, of course, was located the wheel shaft and gearing, and to protect this from the weather there was always a covering or "mill head" or top, and these tops have taken a great variety of interesting forms, for no apparent particular reason, and yet often a fixed style, following some geographical location. For instance, in France the almost universal or characteristic shape is that of a steep true cone; in Denmark, Sweden, etc., a Turk's head or turban type was the standard; also in England, on the great tower mills. Yet in Holland, on the same type of mill, such was never used, but a distinct Dutch form of irregular shape, and almost always thatched. And in the Mediterranean countries the tops become so flattened or

POST MILLS.
All pivoting on single centre post support.



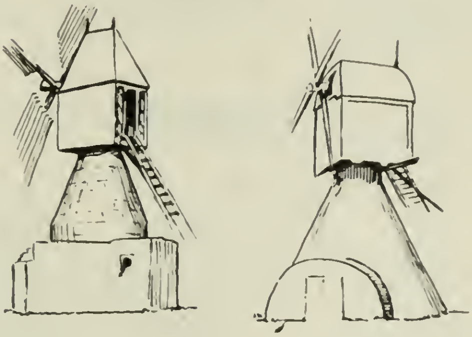
Small form. Large form. North Carolina, U.S.A. England, turret form.

TURNTABLE MILL.



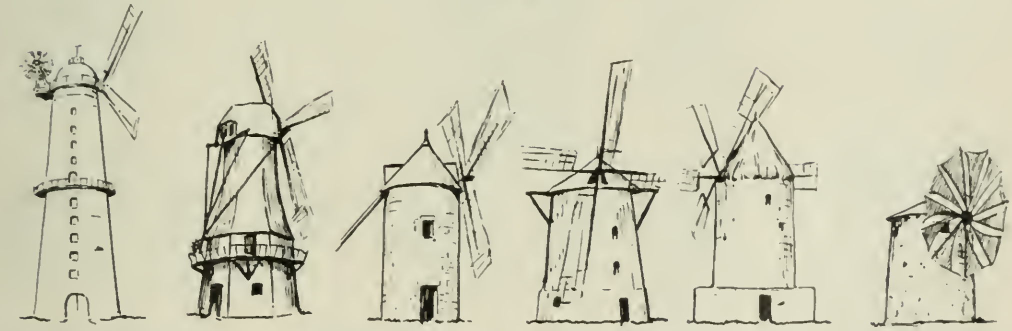
Holland, side and end view.

HYBRID MILLS.



France, grist mill. Holland, dumping mill.

TOWER MILLS.

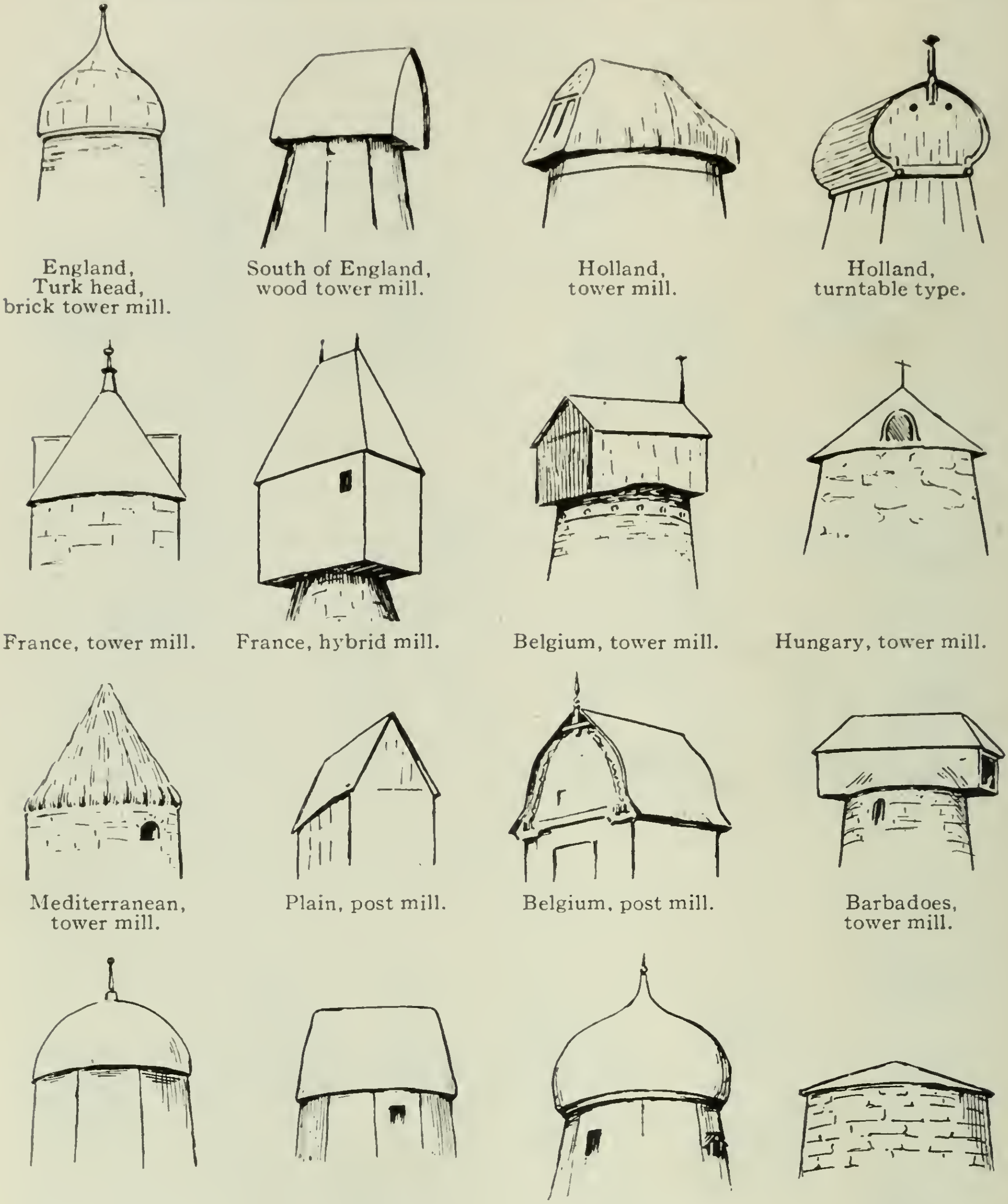


England and Holland, brick. Holland, Germany, Sweden, etc., wood. France, stone. Hungary, stone. Spain, stone. Turkey and Eastern Mediterranean.

THE FOUR TYPES OF WINDMILLS.

lowered as to in some cases almost disappear. The accompanying plate well illustrates these structural and geographical differences.

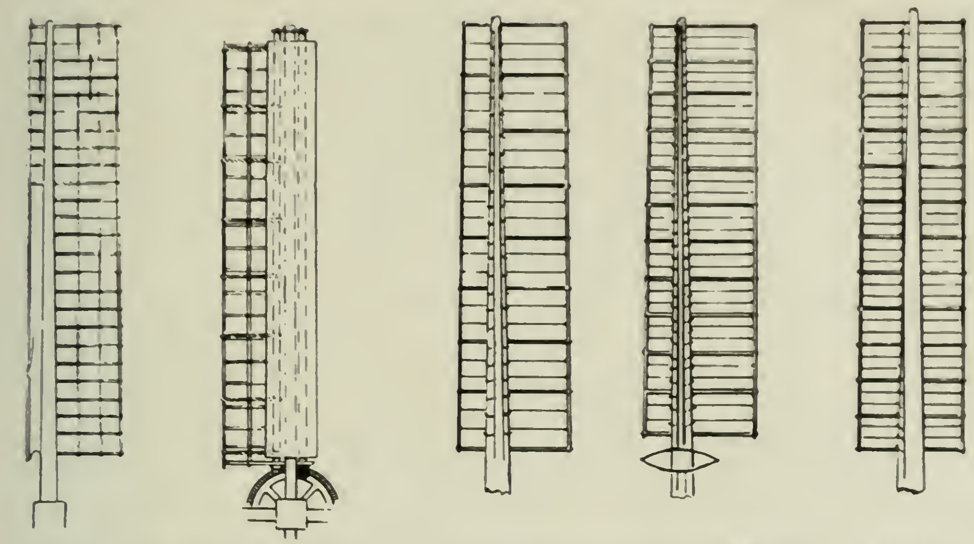
While the old mills all divide into either post or tower mills, there are yet two well-defined further forms, or variations of type, that should be remarked.

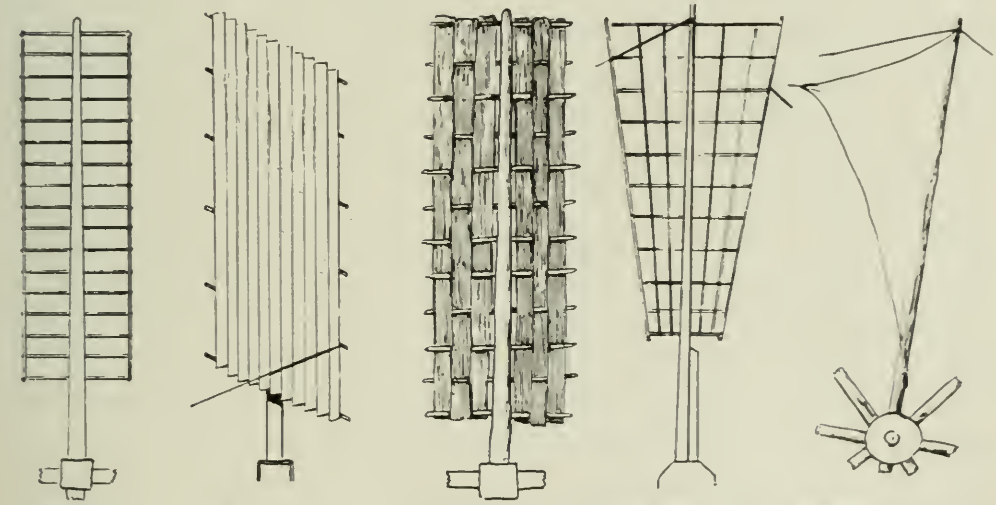


England, Turk head, brick tower mill.
South of England, wood tower mill.
Holland, tower mill.
Holland, turntable type.
France, tower mill.
France, hybrid mill.
Belgium, tower mill.
Hungary, tower mill.
Mediterranean, tower mill.
Plain, post mill.
Belgium, post mill.
Barbadoes, tower mill.
Rhode Island, wood tower mill.
Long Island, wood tower mill.
Sweden, wood tower mill.
Turkey, stone tower mill.

TYPICAL WINDMILL HEADS.

Sometimes a tower mill would be constructed on a circular timber framework or base, carried on rollers or iron balls, forming a large turntable, enabling the turning of the entire edifice to the wind, as need be, the same as a locomotive turntable or a rotary drawbridge is turned. This therefore parallels the post mill type, in which the entire structure is turned to follow the wind, but turning on this turntable base instead of a post. This form was extensively used in the saw mill and lumber districts of Holland.


Usual canvas covered sweep.
England, Bywater's rolling canvas.
England, Cubit's patent shutter.
England, Meikle's spring sweep.
England, double shutter.


France, double sweep.
France, folding sweep.
Primitive sweep, interlaced boards.
Mediterranean, double sweep canvas.
Mediterranean, flying jib; Greece, Turkey, etc.

TYPICAL WINDMILL ARMS.

The other variation is what may be called a hybrid form—part post type, part tower type. In this the contained machinery is fixed in the base, and does not rotate, being thus of the tower mill design; while in the upper part of the mill a rectangular wood housing, like a post mill, is pivoted and revolves with a tail beam, as in the post design. Such hybrid forms are found in Holland and in the valley of the Loire, at Saumur, Chinon, etc.

(*B*) *The Sweeps.*—With mills built for centuries and by all countries, it is but natural to expect to find a wide range of form in this most characteristic part of a windmill—the sweeps or vanes; and in this one is not disappointed.

The usual, earliest and simple form was that of a canvas or sail covered framework. This canvas covering could be reefed to suit the strength of the wind, and the four measures of sail spread were known as " full sail," " quarter sail," " sword point " and " dagger point," respectively—these last two, from a fancied resemblance of the shape of the partly furled or reefed cloth to the point of a sword or dagger. But these canvas sails were laborious to handle, and in no sense automatic in varying the amount of surface according to the strength of the wind, which resulted in numerous schemes for betterment. The most successful of these and that known as "patent" sails was the invention of Cubit, an Englishman, who, a century and a quarter or so ago, devised a series of wood shutters forming the face of the vane, all connected by little levers and cords or rods to a counterweight. This, when adjusted, would cause the shutters to give a full, flat surface to the wind, but if the wind should increase to a danger point, its force would overcome the pull of the weight and the hinged shutters would all open the necessary amount to spill some of the wind through and thus ease the pressure on the sweeps. This was a good deal like a huge Venetian blind arrangement, as to the shutters or slats; and in some cases these shutters worked against the tension of a spring instead of the pull of a weight, and such were known as Meikle's " spring sweeps." Still another arrangement—Bywater's—was that of the canvas being mounted upon a long roller, a good deal like a modern window shade, which rolled and unrolled as needed; but this was rather complicated and not much in vogue.

It was usual to have four-fifths of the area of the sweeps on one side of the arm and one-fifth on the other, and these were "single sweeps"; while those in which there was a wide area on both sides—as almost the universal practice in France—were known as "double sweeps." Wood has been used as a sweep covering as well as canvas—as for instance in France, where one finds some of the most primitive, crude mills, with sails made of thin boards interlaced or woven into the vane framework; while, on the other hand, one also finds quite an elaborate construction. This is in the mills of the Loire valley, in which a dozen parallel boards on each vane are rigged much like a great Japanese fan, which when open presents a large surface, but when closed presents but little, the boards or wood strips overlapping and resting one upon the other. This construction I have found nowhere but in that section.

Going still further toward the primitive, we find in the Mediterranean, especially in the eastern end, in Asia Minor, in the vicinity of Smyrna, Turkey; the islands of Rhodes, Chios, Samos, and of Greece and the Sea of Marmora, a construction consisting simply of poles, anywhere from six to a dozen, stuck in the hub, carrying flying jibs, resulting in a wheel not far different in form from the paper spinwheel that a child may make! In Sicily and the Balearic islands these become a little better, having the wood framework to hold the canvas in the most effective position, and they form a transition phase between the crude jib wheels of the Orient and the elaborated types of the north.

In number the arms of the usual mill were four—and almost universally, for this was not only the simplest and strongest construction compared with the difficulty of framing six or eight firmly at the hub, but also the most effective. For it was found that the wind had to have a certain amount of exit space between the vanes to get away freely, and that if this part of the circle was too much filled with additional sweeps no corresponding gain in power was secured. A few very fine examples, however, can be found of these five- and six-arm mills, as in the famous 100-foot brick tower mill of Whitby, England, with five arms and its Turk's head top; and at Lewes, where a fine turret mill and others have five and six arms.

The length of these arms in an ordinary size mill was about 30 feet, giving a diameter to the wheel of 60 feet; but in the big tower mills referred to the arms were sometimes 50 and 60 feet long, making the wheels well over 100 feet in diameter. The usual speed was about 16 revolutions a minute. If faster than 20 a danger point was reached that was very real, for there have been many cases of runaway mills, resulting from defective brakes or accident or carelessness; in which accidents millers have been caught in the vanes or sweeps and carried around and around and thrown off; or millstones bursting from too high speed have amputated the miller's legs; or friction heat has set the structure afire.

It is of course obvious that the surface of these windmill sails could not be really flat, as in that case the wind blowing against it would merely recoil and exert no power effect. A warp or twist was requisite, that the wind might give a thrust to the sail in passing through the wheel, precisely the reverse action of a screw propeller on a boat.

This twist was known as the "angle of weather" or "bosom," and the precise amount and form were the subjects of many early abstruse and learned studies. Practice finally settled down to an angle of about 17° at the inner end and about 8° at the outer end of the sail as being the most effective.

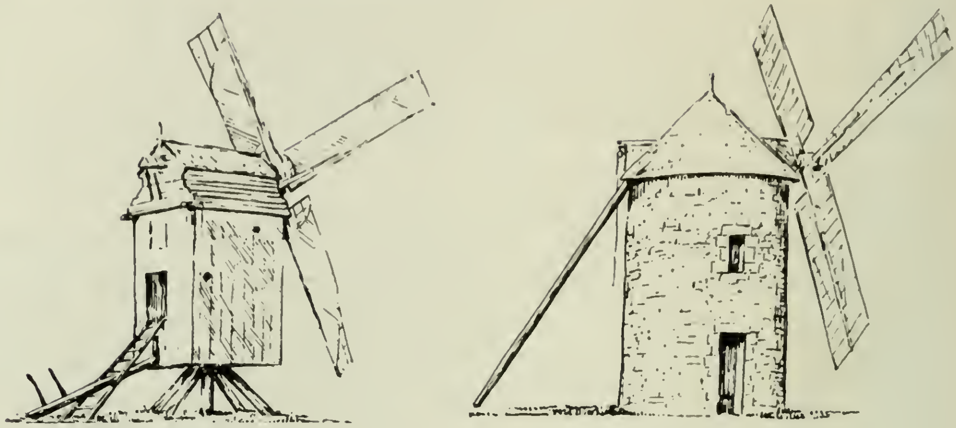
The mounting of these huge wheels was a matter of some moment, requiring very heavy construction, and this resulted in the use, as a rule, in all the earlier and medium size mills of a great shaft or log, turned or hewed octagonal, carried by gudgeon bearings, on old blocks of soapstone, or greased oak, or cast iron bearings at either end. Into the outer projecting end, outside the roof, the square ends of the vane shafts or sweeps were mortised and bound with straps and bolts of iron. Later and in the larger mills, and after foundry work was more available, these "great-shafts" were made of iron, giving much better bearings and enabling the sweeps to be bolted into square openings more conveniently. But with all these mills, especially the early simpler forms, there was an enormous loss in dead weight moved and in friction, and it is doubtful whether in most of them 50 per cent. of the force of the wind reached the mill stones below for useful work.

There was a popular belief that the wind came down from the heavens above, and that therefore the wheel should "look up" a little, to best meet it; with the result that the shaft of the mill was virtually never set level, as one might suppose, but always with the outer end a little higher than the inner, which angle of uplift varied from 5° to 10°. A very practical result of this was also gotten, in the necessary clearance of the tapering tower by the revolving vanes. For these revolving vanes were something to be respected—a 60-foot wheel, for instance, weighing several tons and having a periphery speed of perhaps 3000 feet a minute, and more than one horse or cow straying into the path of the arms in a mill in operation has been struck and paid the penalty. To guard against that, mills were at times set upon a dais or raised foundation, or fenced in.

The great shaft would have mounted upon it a " great wheel," from 8 to 12 or 15 feet in diameter, with cog teeth, and these engaged in a pinion or lantern or trundle or wallower wheel, as variously styled, on a vertical shaft, which led to the machinery below, and there, by any suitable and usual gear work of the olden times, whatever grist, saw, grinding, stamping or other machinery was to be driven would be duly operated by the wind power from above.

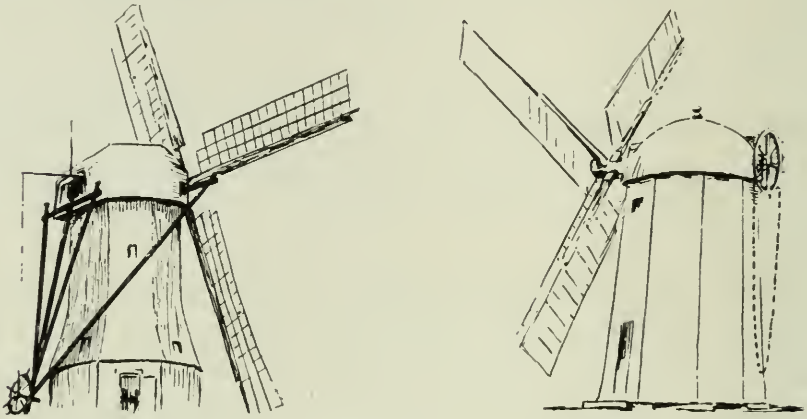
(*C*) *The Tail Beam or Vane.*—The third essential feature of these old mills was the device for keeping the wheel head-on to the wind, for the purpose of securing the fullest amount of power. And this was quite a point, in view of the perpetual shifting of the wind.

The first arrangement was that of a long beam or pole projecting from the rear of the old-time post mill, used precisely like a rudder. When the direction of the wind changed this would be pushed from one side to the other, to steer the post mill structure, pivoted on the post, again into the wind. And in the succeeding tower mills, where only the top or head would be turned, the tail beam principle was continued—as best developed in Holland, where a somewhat elaborately braced and several-membered framework was carried down to a point where it could be reached and moved as the wind shifted. But in Holland the mills became of large size and the weight to be moved was great, so that the old Dutch miller would blow a whistle to summon his hands for help. In later years they made use of a further rig of chains and tackle and a wheel like a pilot's, which enabled the snubbing around of the vanes and cap to be done far more easily than by pushing by hand alone. This old tail beam is, however, characteristic of the old-time small mill, and many are the tracks, well worn and circular, around the mill that betoken the years of labor of the miller, even if eased by an old cartwheel to carry the end of the beam, as instanced in the well-known old mill at Nantucket and elsewhere.



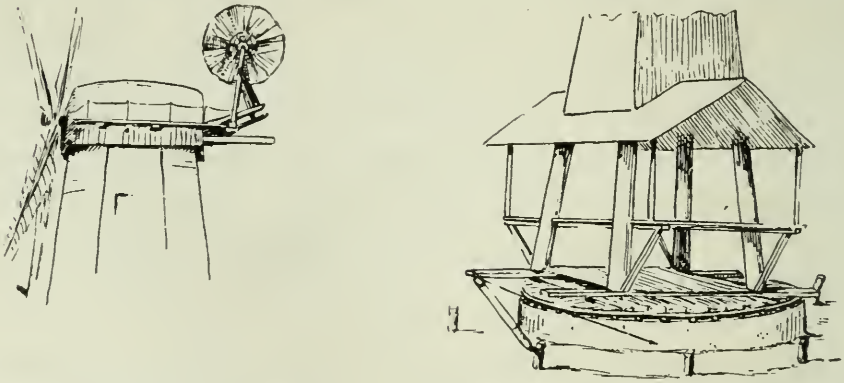
Usual tail beam on post mills and hybrid mills.

Tail beam. France, tower mill.



Tiller on Holland mill.

Chain-wheel on tower mill.



Cubit's automatic tail wheel, England.

Turntable mill, rollers and snubbing posts.

WINDMILL TAIL BEAMS OR TURNING GEAR.
For keeping mill-head on the wind.

Probably the next device for turning to the wind was the use of a chain pull, connected to overhead gear wheels and a cogged track; for not only is this found in some early mills of Holland, and in the mills at Newport, R. I., but also in the rare old Peyto mill at Leamington, England, of 1632, of which I shall speak further. These chain pulls were either inside or out; the former being more protected from the weather.

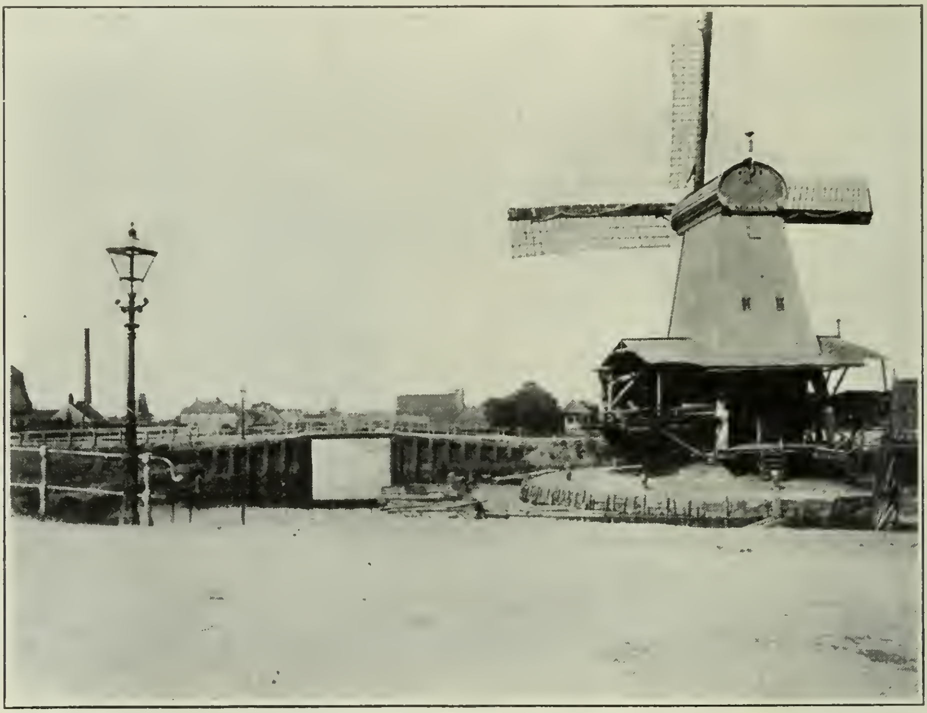
But all these hand devices were completely eclipsed by another invention of Cubit—he of the "patent" sweep-shutter—known as Cubit's tail vane. This was the use of a small wheel of from 4 to 10 vanes, usually 6, placed in the rear of the head of the mill, up aloft, and so connected by a train of small gearing that when it rotated it would turn the main head a little, and if need be follow up the variations of the wind. So accurately was this designed that it is said that even with the wind shifting but a couple of degrees around the horizon the tail wheel would then begin to turn, and with its gearing would in turn wind the mill head, carrying the sweeps, into the wind. This automatic arrangement was almost universally adopted in England, in the better class of mills; yet, with the stolidity of the Dutch temperament, apparently content to continue with hand labor as did their grand-

Thatched tower pumping mill. Holland.

fathers, this admirable device was rarely transplanted even to a place as nearby as Holland.

Turning now from the mechanical side of these old mills, as above, it is interesting to note the varied forms, uses and characteristics as found in the diverse parts of the world, and in the variety of races where and by whom these old home-made motors have been used.

Holland is usually taken as the home of the windmill, but that is so only in the greater proportionate number there in use than elsewhere. It is not true as regards origin nor the best development of them. It is a country notably flat, without water power, on the sea coast, and requiring great pumping equipment for draining, etc. This early resulted in the great number of windmills there found and associated with that little kingdom. It is said that in early days there were 10,000 of them. The greater number of them were used for lifting water to drain the "polders," or meadows or lowlands, through the medium of a scoop wheel or Archimedes screw. Some of them can yet be seen and in use, with fat Dutch babies apparently ever on the edge of falling in the sluiceways, yet never doing so. Nearly all of

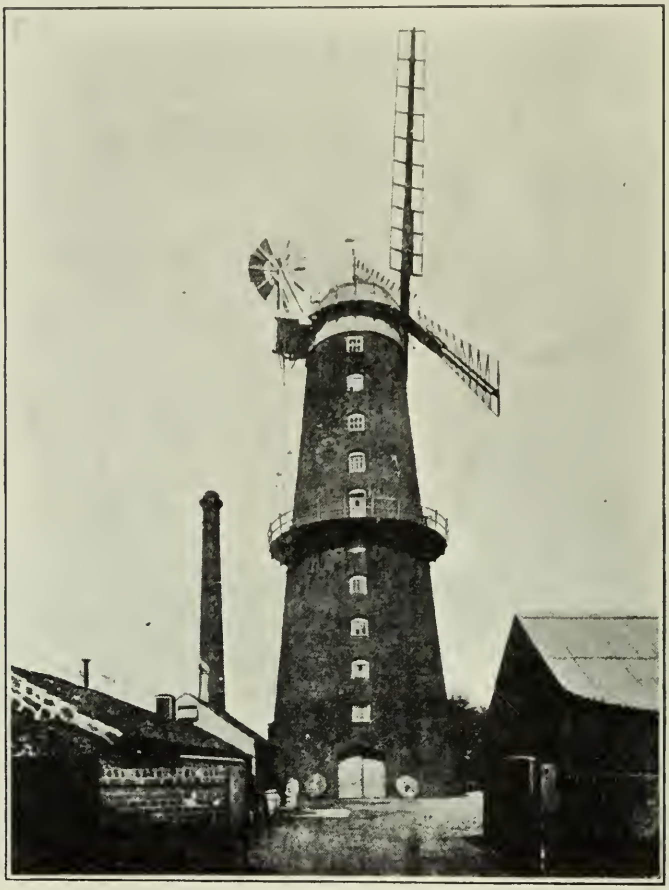


Saw-mill; turntable type. Holland.

these mills have been replaced by great steam-driven government pumping stations. For sawing wood, also, great numbers are yet used in the Zaandam district, where several hundred can be seen almost adjacent, a vista and forest of windmills. And in the heart of the chief cities one yet sees, here and there, an old-time brick tower mill, probably 200 years old—a family heritage, with its clean and trim curtained little Dutch windows, its individual name, as of a ship, such as "The Admiral" or "The Parrot," over the door, and its old coat of arms and carvings and touches of color. For the Dutchman is fond of his substantial woodwork, and of his bits of color; and such finds expression in his mills, where carving like the stern of an old galley and color stripings of all the rainbow are both tucked in and flagrantly added.

"Petmolen" or small pumping mill. Holland.

The characteristic of the Dutch mill is, however, that of a thatch covering, both on sides and top, on the usual size common mill—something not found in any other country. It is said of them that there is also a code worked out—sort of a wigwag or semaphore system—so that by the position of the vanes as left when shutting down, the long-distance observer can read whether a carpenter is needed or a baby has been born, etc., etc. Certain it is that the mills make fine elevations for flag-flying on holiday occasions, for then the staunch colors of Holland will be found on the flagpoles atop the most of them. In noting the Dutch mills, one cannot overlook—nor wants to—the picturesque little " petmolens " or " jaskers "—diminutive post pumping mills, for small fields only—that, with long, slender vanes, seen through the haze or afar, almost suggest one of the old rocs from Sinbad the Sailor, caught in the act of alighting.

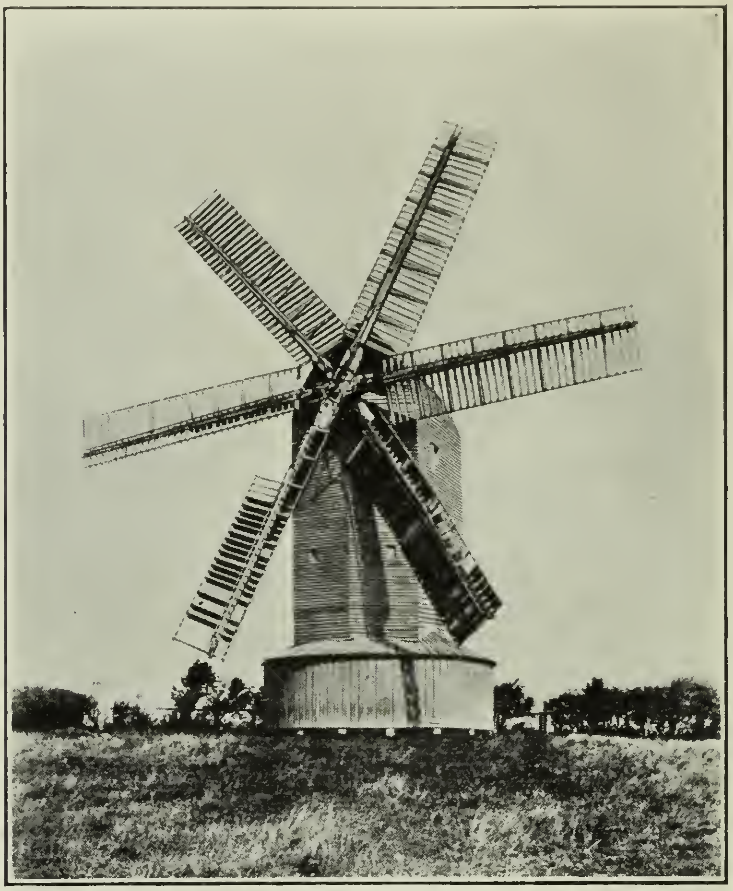


Brick tower mill; largest built. Great Yarmouth, England. (With Cubit's tail vane.)

England, while numerically far inferior to Holland, is yet far in advance from the viewpoint of the fullest engineering development of this world's motor, as may be gathered from what has been said above as to the automatic shutters, tail vanes, etc. The largest, the most varied and the most efficient are found there. Many fine examples of these mills can be seen, a few of which are still in operation. In the south of England there are plenty of old wood structures of all forms—of which the turret is perhaps the most locally characteristic. This is a huge, or at least large size, post mill, often for some fine estate, with the base enclosed with a circular low or one-story building, used for storage, so that the external effect suggests a turret. In central England a good number of the tall brick tower mills yet stand.

Tower grist mill. South of England.

For picturesqueness, however, no country surpasses old France. There the mills are small; the huge, towering structure of the Dutch and English is unknown. But one can find many of great antiquity, great variety of form and of great charm. The type seems to be the true cylindrical tower—not tapering—with the cone top. In the racetrack at Longchamps, near Paris, is an instance, while on the golf course at St. Lunaire, overlooking the sea coast, on the Channel, as in innumerable other places in the northern part of France, these little sentries of the past can be found. Picturesque as they are, however, they are not yet as much so as even an older and cruder form suggesting an old blockhouse. For above the stone first story is an overhanging wood second story, as so well instanced at St. Briac. And in the Loire valley are the very unique hybrid mills with the folding boards vane arrangement, already referred to, which at Saumur date back to 1682, as doubtless do the others of that not-to-be-found-elsewhere form.



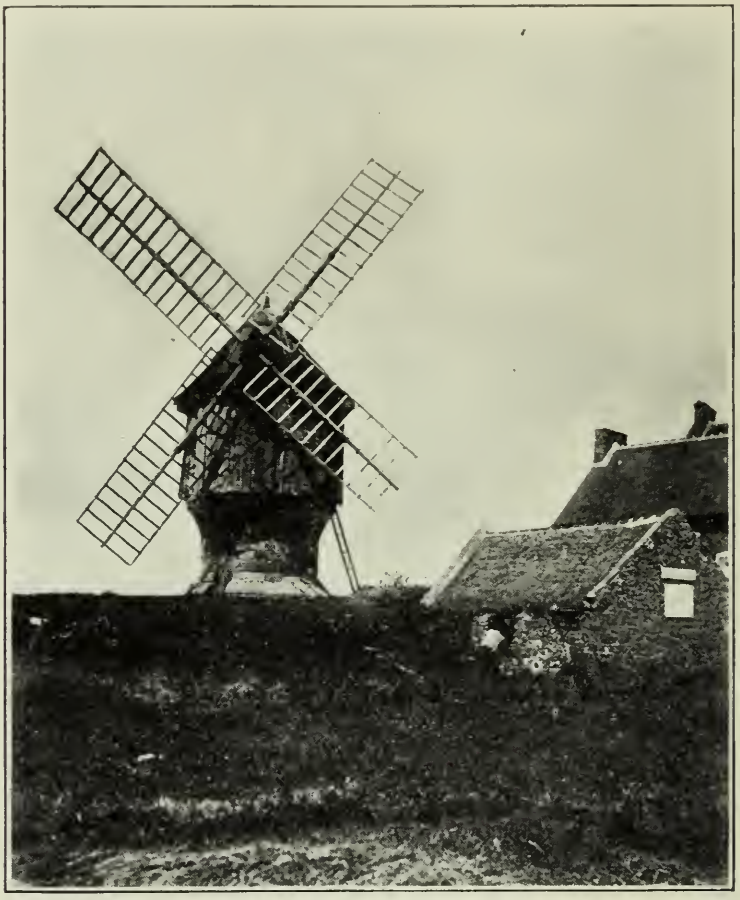
Turret post-mill. South of England.

Of old post mills of the usual wood form France has plenty, of which the one on top of Montmartre, in the Moulin de la Galette grounds, is perhaps the most prominent. It is one of the two or three remaining that were part of a dozen or more that crowned that hill in the early days, as shown in several views of old Paris. What changes it has seen in its 600 years of accredited age! In its timbers are shot and balls of the revolutions of 1814 and 1871. Within are the old bells and bunks and shrines of the generations of millers who operated it, one of whom is said to have been killed and quartered and hung on the four arms of his own mill by the successful assailants. In the same premises is a dear little miniature mill, which, with diminutive stones of but 18 or 20 inches in diameter, was used for grinding spices, in place of the usual grain for bread.

Tower mill and tail beam. St. Lunaire, France.

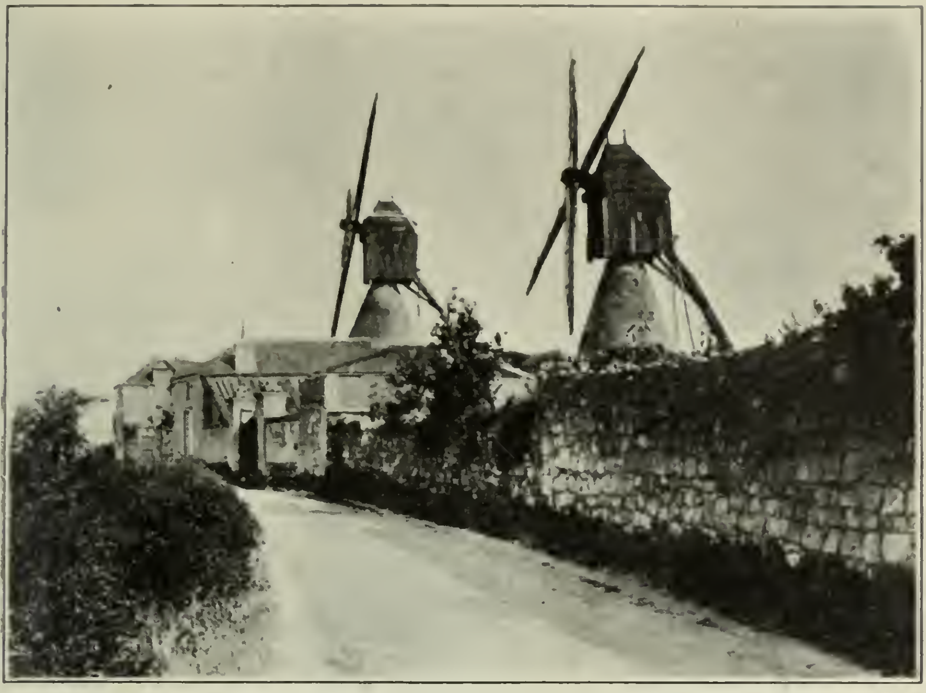
In Belgium we find, in the main, the post and tower mills of

Holland and the Netherlands; while in Germany, as well, the similarity to the Dutch mills is the only or chief characteristic. In Denmark and Sweden and in Iceland are the usual mills of this section, excepting that their octagonal, typical squatty grist mill nearly always has the Turk's head top instead of the irregular shape of Holland and Germany. And so pronounced is that that in Lawrence, Kan., where a mill was erected in 1858, with a Swedish top, inquiry develops that it was by Swedish emigrants. Iceland can claim probably the most northern mill ever erected, for in Reykiavik, a little isolated town of about 3000 inhabitants, we find an old mill, probably the first and only motor in the early days in Iceland.

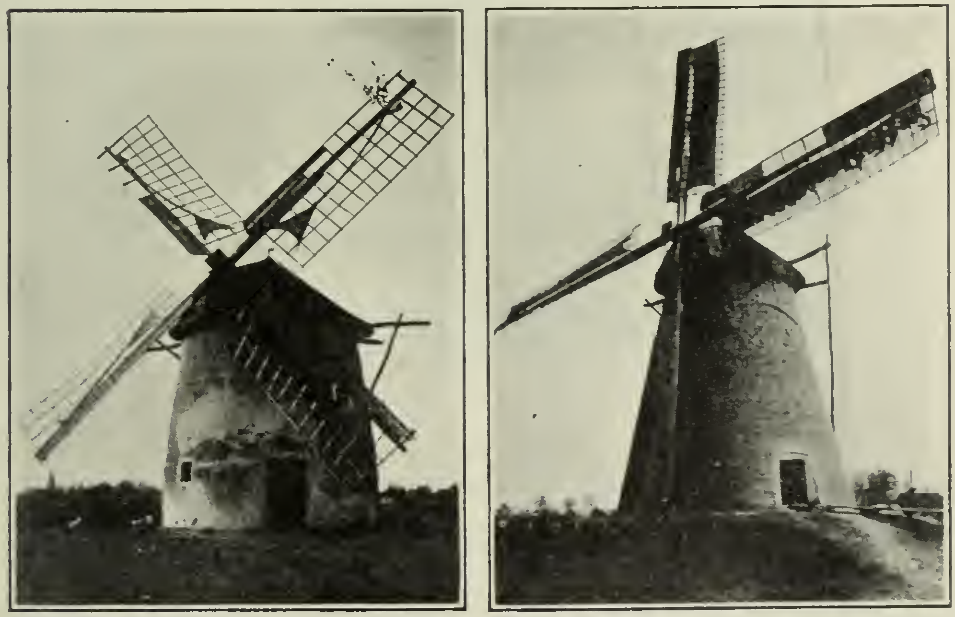


Tower mill; double sweeps. St. Briac, France.

There is greater picturesqueness—but, as usual, accompanied with less efficiency—in the southern part of Enrope, as, for instance, in Spain. Here, aside from the jib flying mills of the

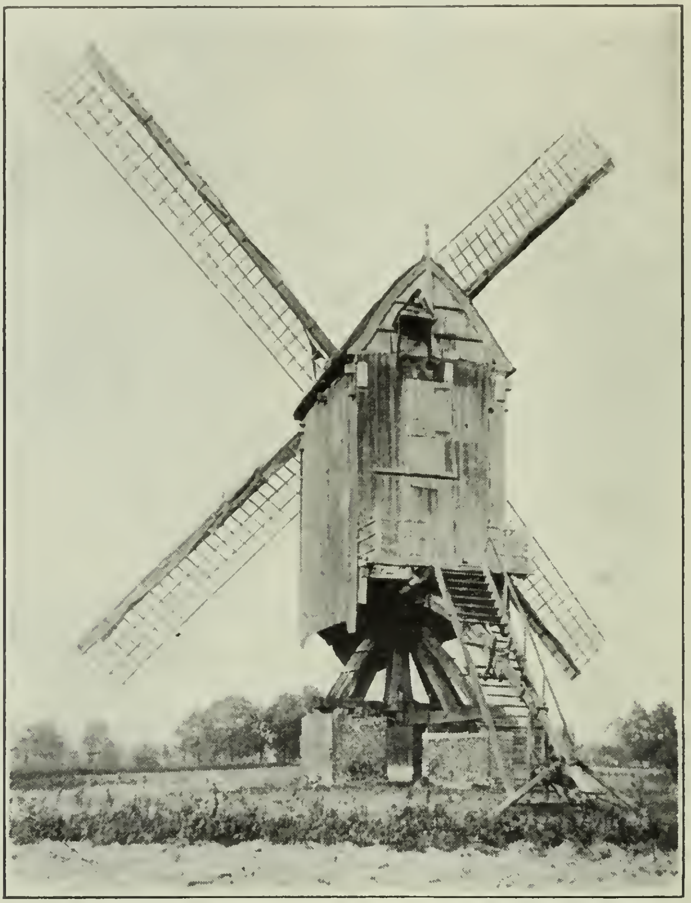


Hybrid type of grist mill, 1682. Saumur, France.



Crude forms of tower grist mills; vicinity of Buda-Pesth, Hungary.

Mediterranean, we find primitive construction, crude devices and even the clay water bottles, or jars, bound to a cumbrous wheel, slowly turning over by wind power, for lifting water for irrigation, similar to devices seen on the banks of the Nile—although there operated by oxen. And in Spain we tread the country where the ever immortal Don Quixote, despite the adjurations of the faithful Sancho Panzo, charged at full speed a flock of windmills on the plains of Montiel.

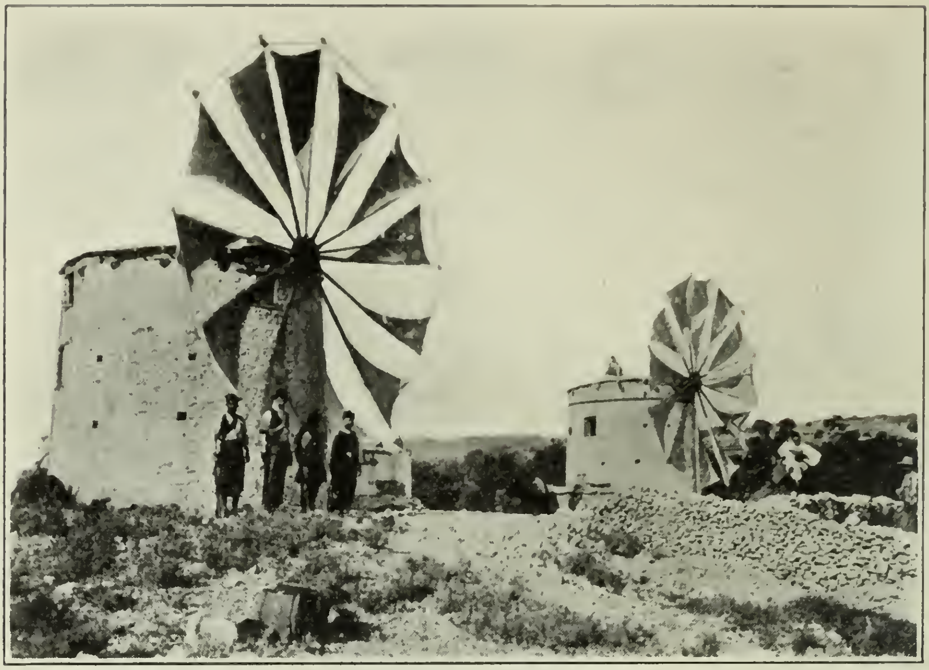


Mid-European type of post mill. Belgium.

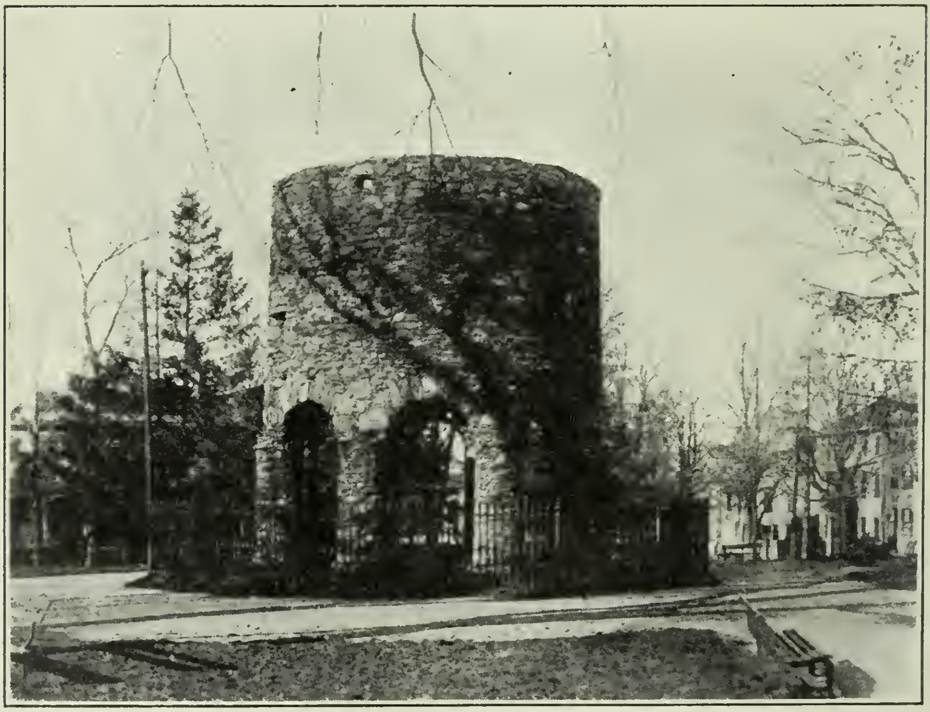
The crude structures of Greece and Turkey, already mentioned, are so crude that often no device is provided for turning to the wind, but, on the contrary, four mills are sometimes built in a field, facing, respectively, north, south, east and west; so that whichever way the wind comes some power can be secured. It is, however, more likely that prevailing winds are so constant from one quarter there is but little use for a turning device, resulting in its omission.

And so one can go the world over and find these old mills; to the Barbadoes, where they are still extensively used—and of English type—for crushing sugar cane; to Jamaica, where they once were, as shown by an old print of the earthquake of 1792, in which several mills are depicted bodily upside down almost, as would be a child's toy; to Peru, where over 13,000 feet above sea level in the Potosi silver mining districts of past times—centuries past—old prints show mills of the manifest Spanish type operating stamps for crushing silver ore; to the St. Lawrence, where the early settlers, both French and English, left their imprint in the shape of old mills on several promontories and points; to southern Illinois, where the German emigrants of the

Tower mill. Trapani, Sicily.



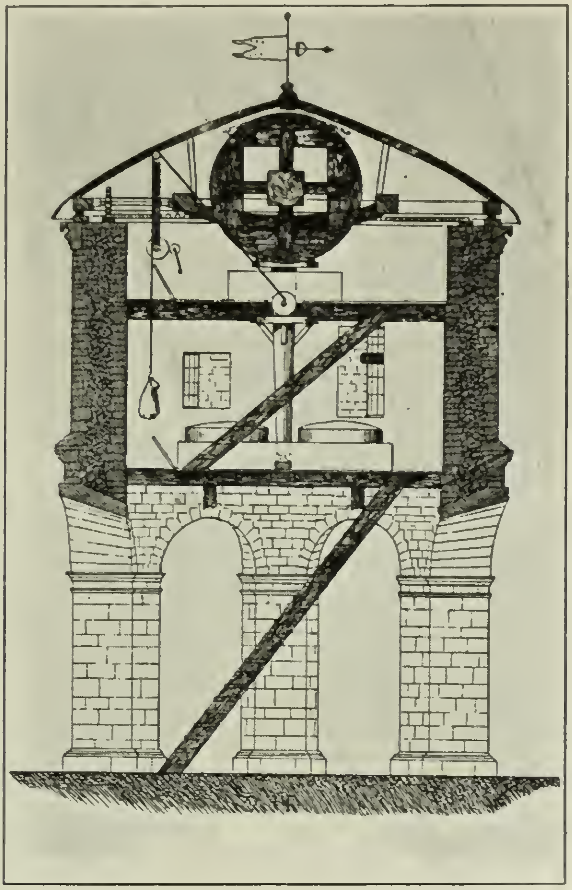
Multi-jib tower mill. Samos, Turkey in Asia.



Tower of the old Newport mill, of 1675, as now standing. Truro Park, Newport, R. I.

1820's and '30's brought with them the mills of the Fatherland, etc. In all quarters of the globe the world's chief motor for eight centuries can still be found.

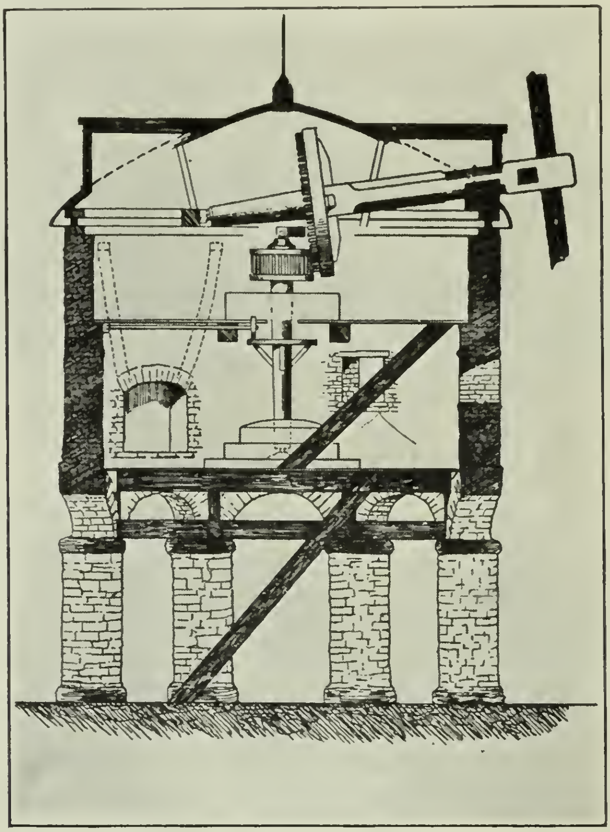
And in closing this review of old windmills there is no instance to which reference should be made of quite as much interest as the old mill at Newport, known to every American antiquary and which, some two or three generations ago, was ingeniously ascribed to the Norse in the period of 1100 or thereabouts. This theory, while highly picturesque, was unfortunate chiefly in never having anything except surmise to back it up. Not a jot nor tittle of record or physical remains could be developed to substantiate it, and it has long since been practically dropped by most students of American history. And when the following, that has in recent years been developed, is borne in



Chesterton mill, vertical section between columns.

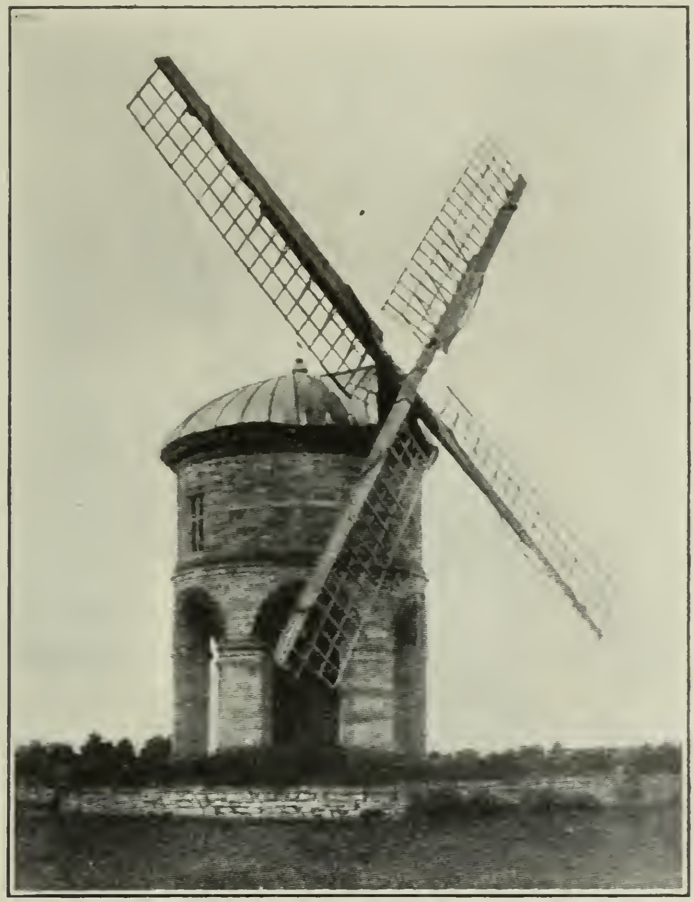
mind, there seems no vestige of reason left in the Norse theory. There is no question as to the following facts in relation to the Newport mill, and I speak with confidence, having in person surveyed and thoroughly investigated both it and its English prototype, as described:

In 1675 Governor Benedict Arnold (the grandfather of the traitor) was in charge of the then early colony of Rhode Island. Sixty years before he had been born in the Warwickshire section, England, in which the Peyto estate was perhaps the greatest and finest. On that estate there was completed the most elaborate windmill ever built. Inigo Jones, England's great architect of that time, designed it, and it was unique in its open arch design, its finely chiselled stonework and unusual adornment. Young Arnold was a lad of 17 at that time, and the building of this beautiful and remarkable windmill, in 1632, was, with small



Newport mill restored, vertical section.

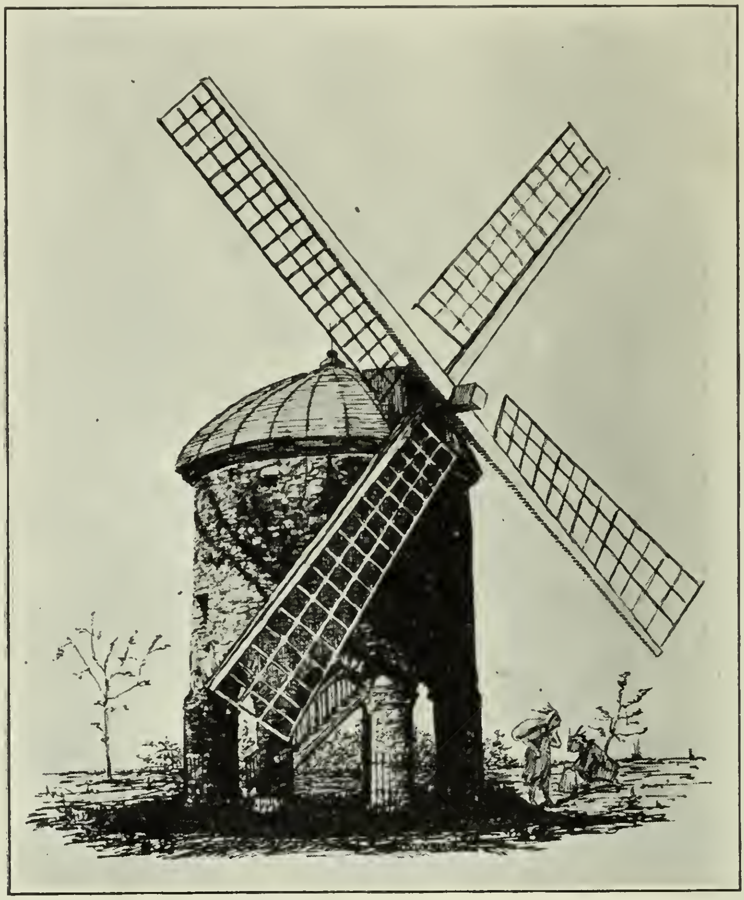
doubt, a marked episode in his life and knowledge. Forty odd years later, he, by the chance of fate, was the Governor of the Rhode Island Colony. With the destruction of a previous wood windmill of 1665, blown down in a great storm, it became his duty to provide another one for the use of the little colony. And there is small doubt, indeed, that in doing that he undertook to provide a mill that should be as nearly as possible a copy of the old mill at Chesterton, near Leamington—the best mill of which he knew. And so, without the measurements as to the general arrangement, size and design, from memory only, he there built, with the most limited facilities, a virtual replica of the Leamington-Peyto-Jones mill. In order to secure greater



Inigo Jones-Peyto mill of 1632. Chesterton, Warwickshire, England.

permanence and protection against Indian attacks the mill was built of stone instead of wood.

For, while of course the fine stone work and carving and detail are missing, in this colonial condition, the general dimensions, the design and the interior arrangements are in substance the same throughout. It needs only the comparison of the plans of the two—side by side—to be satisfied as to that. Governor Arnold's birthplace and connection afford the reason of the similarity, and his will even speaks of "my stone built windmill." This old structure, still standing—as to its walls—in Truro Park, Newport, R. I., is perhaps America's greatest colonial relic, and with its prototype of Chesterton constitutes the most unique pair of windmills, having the greatest historic interest, of any attaching to our country's windmill history.



Newport, R. I., mill as "restored" or probably constructed.

A NEW THEORY OF PLATE SPRINGS.

BY

DAVID LANDAU and PERCY H. PARR.

PAPER 3.

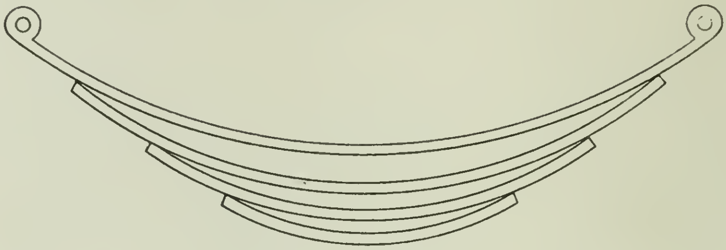
Our second paper dealt comprehensively with the general relations between the various plates, their deflections, and the permissible external loads, for all plate springs, and also considered in detail numerous different types of leaf "points," sufficient in variety to cover all of the ordinary commercial springs in use at the present time. This third and, for the present, concluding paper will deal with two of the most important of the remaining questions. These are: first, the "nip" stresses, and, second, the "life" of the plates under the varying stresses produced in the metal when in use.

We have previously mentioned that when a leaf spring is manufactured the leaves are shaped to different curvatures, as indicated by Fig. 32, and this regardless of the number of leaves, their thicknesses, widths, etc. Now, when such leaves are assembled to form a spring, it is patent that each leaf will be deflected, more or less, in either a positive or a negative—down or up—direction, with the result that there is produced an "internal" stress in each of the leaves comprising the spring. The clear distance between any one plate and the next, measured at the centre, when the plates are placed in contact at the ends, but without pressure, is termed the "nipping distance," or the "nip," and the stresses produced by clamping or bolting up the plates so as to contact at the centre are called "nip stresses." The term "nip" is of English origin, the American spring-maker's shop phraseology being "pull" or "tension"; we ourselves prefer and shall use the English term as being the more expressive.

It will shortly be shown that the nip stresses, acting in conjunction with the stresses produced by the external loads, are of vital importance, for it is the combination of the two stresses, produced by the nip and external load, or the static and dynamic stresses properly combined which determines the life or endurance of each plate in a spring.

The study of the nipping stresses has been almost wholly neglected by nearly every writer who has contributed to the study of the leaf spring, and we have never seen any paper in which the real utility and sometimes even the necessity of nip was pointed out. The existence of the nip stress has been mentioned by Prof. Perry in his "Applied Mechanics," where he says that to overcome the effects of "this objectionable practice the shorter plates should be made thinner." Of course this would reduce the nip stresses, but cannot wholly remove them; neither is it always desirable to do so. Paul Brennier, in his excellent memoir, "Etude sur les Ressorts."[1] has recognized the evil effects produced by these internal stresses, but we are reasonably assured that no writer had studied the question in connection with the strength and life of a spring until the advent of the year 1908,[2] when one of the writers suggested and applied the endurance test to plate springs. The authors take the opportunity here afforded to state that most of the test results mentioned in the present paper were undertaken and carried out in the laboratories of the Sheldon Axle and Spring Co., of Wilkes-Barre, Pa., during the years 1911 to 1916. They are under deep obligations to this company and especially to their vice-president, Mr. Geo. M. Wall, for the many facilities he has afforded them to carry on this work.

Fig. 32.



At first sight it would appear that the practice of introducing any nip into plate springs is most objectionable; the further consideration of the conditions involved, especially in the operation of automobiles, shows that the nipping of the plates during the manufacture is not only desirable but sometimes absolutely necessary. In the case of springs which are never unloaded, the nip is not required, and is certainly undesirable if present in any appreciable amount. For example, in railroad springs, where the vehicles run on a smooth metal track, the nip introduced during manufacture is very slight indeed, being no more than is required to insure that the plates contact properly. On the other hand, for automobiles and motor trucks, it is found, both theoretically and practically, that nip is not only desirable but is in fact a necessity. We shall show in due course that the nipping of the plates increases the endurance of the upper plates in most cases and particularly that of the very important master leaf, which is one of the advantages of introducing the internal or nip stresses. Of course, the reduction of the probability of breakage of the main leaf is only obtained at the expense of the other leaves, but they are comparatively of less importance; their breakage does not put the vehicle out of commission as in case of the main leaf breakage; the short plates are much more readily replaced, so that on the whole the advantage gained is considerable.

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[1] *Bulletin de La Soc. d'Industrie Minerale,* April, 1912, to April, 1913.

[2] See article by J. E. Bishop in the *Australasian Coach Builder and Wheelwright,* entitled, "Springs," appearing in the issue of March 15, 1906, to January 15, 1908.

There is another point of practical importance, namely, that after encountering a sharp obstruction, as often occurs on an ordinary road, the wheels of an automobile frequently leave the road for quite an appreciable time; in such a case the springs may be and often are completely unloaded, even passing quite beyond the unloaded position on the "rebound." Now, if there were no nip in the springs, then, as soon as they reached the free position, the plates would separate, and in coming together again they would "chatter," making an objectionable noise. This fact is well known. One other point—if there were no nip, then, as soon as the spring reached the free position, there would be nothing but the stiffness of the master leaf to take care of the rebound, while with a spring which has been made with nip, the lower plates have an effect in increasing the stiffness of the whole spring for some little distance beyond the free position.[3]

We will now consider the intensity of the internal stresses produced by the introduction of the nip during the manufacture of the springs, and it will be found that the previous work given in our first, and especially that in our second paper, will greatly simplify the study of the question.

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[3] See paper entitled. "Influence Affecting the Fundamental Deflection of Leaf Springs," by David Landau, in the Transactions of the Society of Automobile Engineers, 1914; also a paper entitled, "Apropos des Contre Ressorts," by A. Contet, *La Techn. Auto et Aerien,* July 15 and August 15, 1912.

For the calculations of the nipping reactions and stresses our experience has shown that it is best to consider a spring as being built up by the addition of successive plates, commencing with the shortest. Thus, we shall first consider the reaction or pressure resulting from the clamping up into contact of the shortest plate with the adjacent short one or the second short plate; then we will consider the reaction resulting from the clamping of the third short plate *to the two-plate clamped partial-spring first obtained;* and a similar reasoning is then to be continued for all of the plates until the spring is complete.

For the analysis indicated we will let N_n be the distance between the nth and the $n+1$th plates when they are in contact at the ends without pressure—that is to say the nip distance—and let nip $(1 \ . \ . \ . \ n) - n + 1$ be the nip distance between the partial spring of n plates and the free $n+1$th plate.

Now, on referring to the second paper, page 709, it will be seen that on adding the second shortest plate to the shortest one, or Plate No. 2 to Plate No. 1, and clamping up to contact at the centre we must then have

$$Y_1 + y_3 = N_1, \text{ or } (B_1 + A_3)\ W_1 = N_1$$

so that the nip pressure between the two plates will be

$$P_1 = \frac{N_1}{B_1 + A_3}$$

we use P for the nip pressure or nip reactions in order to obviate any confusion between the reactions produced by the nips and those produced by the external loads; they are of a similar nature, and they act at the same places, but it has been found advisable to use a different symbol for each so as to avoid the possibility of confusion in identification. The symbol P_n as here used may be defined as the nip pressure or reaction produced when the nth plate is added to the $n-1$ plate partial (clamped) spring.

Next, for the nipping reaction between the third plate and the two-plate clamped spring, we must note that the nipping distance will not be N_2, which is the nipping distance only when all the plates are free; the dimension N_2 will have been modified by the deflection of the second short plate produced by clamping it to the shortest plate. Again referring to our second paper, it will be seen that the upward deflection of the second plate, due to its being clamped to the shortest one, will be P_1A_4, and therefore the total nipping distance when the third plate is to be added to the two-plate spring will be $N_2 + P_1A_4$, and it follows that

$$\begin{aligned} N_2 + P_1A_4 &= y_7 + Y_2 \\ &= A_7P_2 + B_2P_2 \end{aligned}$$

from which there is obtained

$$P_2 = \frac{N_2 + P_1A_4}{A_7 + B_2}$$

and similarly, for the nip $(1\ .\ .\ .\ n) - n + 1$, the nipping distance will be $N_n + A_{4n-4}P_{n-1}$ and we shall have

$$N_n + A_{4n-4}P_{n-1} = (A_{4n-1} + B_n)\ P_n$$

from which

$$P_n = \frac{N_n + A_{4n-4}P_{n-1}}{A_{4n-1} + B_n} \quad \dots\dots\dots\dots (55)$$

and the successive use of this equation (55), with gradually increasing values for n, will determine the internal reactions produced by the nips.

It must be noted that for each step equation (55) gives the value of the nip reaction between the $n+1$th plate and the n-plate clamped spring, when the $n+1$th plate is added; this reaction can be considered in the nature of an external load on the n-plate spring, and therefore the internal reactions between the lower plates will be increased in the same manner as if an external load of the same amount was applied to the partial spring. For example, when the third plate is added to the two-plate clamped spring, the nip reaction between the short and the next plate will be increased by an amount equal to N_2W_1/W_2, or to N_2C_1. The nipping reaction for each additional plate affects all of the lower plates in a similar manner, and the calculations should therefore be carried out in the manner shown by the following example, which is the front spring of the United States Government's Liberty B standardized truck.

This is a ten-plate spring in which the plates have the half-lengths of 5, 7⅛, 9¼, 11⅜, 13½, 15½, 17½, 19½, 21½ and 21½ inches respectively for the short end. The long end is one inch longer overall, and the lengths of the other plates are all practically in the proportion of 22½, to 21½ to the lengths mentioned. The lower eight plates are all 3″ × 5/16″ and the two plates forming the "compound" top plate are each 3″ × ⅜″. The nip distances, when the plates are in contact without pressure are, measuring from the short plate upwards, 1/32, 1/32, 1/16, 1/16, 1/8, 3/16, 5/16, 7/16, and 7/16 inches respectively (these figures were taken from *one* only of the actual springs).

The calculated reactions W for the external load are 1.000, 1.221, 1.296, 1.327, 1.341, 1.363, 1.376, 1.385 and 1.363 respectively. The calculated stiffness, taking E as 29×10^6, is 1057 lbs. per inch deflection. The test loads of an actual spring were 1070 lbs. at 1″ deflection, 1565 lbs. at 1½″, 2070 lbs. at 2″, 2580 lbs. at 2½″, and 3100 lbs. at 3″, which agree within the limitations of practice with the calculated stiffness.

The fundamental constants for this spring, obtained as indicated in our second paper, are found to be as follows:

n	A_n	B_n	C_n	W_n
1	.0002149	.0002149	.8187	1.000
2	....	.0003337	.9419	1.221
3	.0002149	.0005124	.9768	1.296
4	.0003518	.0007434	.9895	1.327
5	.0006217	.001024	.9840	1.341
6	.0003518	.001315	.9901	1.363
7	.0006217	.001648	.9935	1.376
8	.0008999	.002031	.9062	1.385
9	.001360	.002203	.7442	1.528
10	.0008999	.001785		1.861
11	.001360			
12	.001829			
13	.002530			
14	.001829			
15	.002530			
16	.003239			
17	.004229			
18	.003239			
19	.004229			
20	.005169			
21	.006401			
22	.005169			
23	.006401			
24	.007640			
25	.009212			
26	.007640			
27	.009212			
28	.01079			
29	.01275			
30	.01079			
31	.007291			
32	.008448			
33	.009859			
34	.008448			

In the above table it will be noticed that values for C_n are given for both 8 and 9 as the value of n. When dealing simply with the reactions due to the external load, the top compound plate is considered as a single plate with a moment of inertia equal to the sum of the moments of inertia of the separate plates, as has been mentioned previously, but when we are dealing with the nipping reactions, it is necessary to consider every plate separately; that is, as in the present case, we must consider the partial spring obtained by adding the 9th plate to the 8-plate partial spring, and also consider the complete spring obtained by adding the 10th plate to the 9-plate partial spring. As the 9th and 10th plates are of the same length, then for calculations concerning the external load they need be considered as only one plate, but, as indicated above, for the nipping reactions they have to be taken separately as in the previous table.

The nipping reactions may now be tabulated as follows:

n	N_n	P_n	P_n (total)
1	.031	7	420
2	.031	35	505
3	.062	50	499
4	.062	47	460
5	.125	53	417
6	.187	60	370
7	.312	71	313
8	.437	129	244
9	.437	127	127

In the preceding table, the P's are of course those calculated by the successive application of equation (55). The P's (total) are determined thus: P_9, or the reaction produced on adding the 10th plate to the 9-plate partial spring, is equal to 127 lbs.; the relation between a load on the end of the 9-plate partial spring and the reaction between the 9th plate and the 8-plate partial spring is $W_8/W_9 = C_8 = .9062$ and $127 \times .9062 = 115$. Adding this to the nipping reaction of 129 lbs. produced when adding the 8th plate to the 7-plate partial spring, the total nipping reaction between the 8th and the 7th plates will be 244, as given in the table. Similarly, the total nipping reaction between the 7th and the 6th plates is $244 \times .9935 + 71 = 313$ lbs. A continuation of the same process determines all of the nipping reactions, as given in the table above under P_n (total).

We may here note that these nip calculations determine the amount of the camber to be given to the master leaf in forming. In the case under discussion it is seen that the final total nipping load on the master leaf or 10th plate is 127 lbs. and the deflection produced by this load is $127 \times .009859 = 1.25''$, and therefore the master leaf must be formed with a camber $1\frac{1}{4}''$ less than the desired camber for the assembled spring; this was actually the case for the spring measured.

We may now say that, in the absence of the theory as developed in the previous papers, the present study of nip and nip deflection would not have been possible, but that with the application of this theory very many results which have been observed in practice may now be accounted for. Other results of practical importance but, somewhat foreign to the present paper, have been predicted from the theory and have been confirmed in actual use.

ENDURANCE OF PLATE SPRINGS.

We now enter into the final stage of the present exposition, which is that of the " life " or " endurance " of the plates composing a spring under the stress variations experienced in actual service.

In the past the commercial value of a spring or its " strength " was usually measured by the static load it would support without taking a permanent set, or else, as was the practice of the French spring-makers—and amongst them, the most renowned of all, the Etablissements Lemoine of Paris, France—by the elastic elongation of the material. It was believed formerly, due to the teachings of Mons. Lemoine, and is still perhaps held to be the case by some engineers, that the greater the elastic elongation or the higher the elastic limit of the material, the greater is the " strength," and also as a result the endurance or life of a spring. We have found, however, that this condition does not necessarily hold, and at least it is certain that there is no linear relation between the elastic limit of the material and the life of a spring.

It is a well-known and accepted fact in applied mechanics that any piece of material will withstand a considerable number of applications of a load (within the elastic limit) provided the said load does not produce stresses varying in sign from positive to negative—tension to compression—and that when the load produces stresses varying in sign, then the material subjected to such alternating stresses breaks down more rapidly. For instance, as a practical illustration, if we have a piece of metal bar and wish to break it by hand without exerting any great force we bend it back and forth, so as alternately to produce positive and negative stresses, and this procedure rapidly breaks the bar, even with a ductile metal which will bend double on itself—lead, for instance.

The stresses in the plates of a plate spring due to the nip are not of the same sign in all of the plates, and the amount of the stress, and in some cases its sign, will change when the external load is applied. In a spring composed of more than two plates we may find, under certain conditions of the loading, plates or parts of plates with zero stress—that is, the positive effect of the external load may exactly neutralize the negative effect of the nips; this is of great importance.

As a simple illustration, for a mental physical conception, we may take, say the two-plate spring shown in Fig. 5. When these two plates are bolted together at the centre, the master leaf is deflected *upwards,* or negatively; the short plate, on the other hand, is deflected *downwards* or positively (in the same direction as it is deflected by the external load) and hence there is a negative stress produced in the master leaf and a positive stress produced in the short leaf during the manufacture—all before any external load is placed on the completed spring.

Suppose we now deflect this spring positively, as by placing an external load on it, then both leaves move in the positive direction and when the master leaf has been deflected a distance equal to the initial negative deflection due to the nipping load, it will have (at certain places) zero stress, while at the corresponding deflection the stress in the short plate is positive and is equal to the sum of the nipping stress and the load stress. The total stresses and the stress variations are quite different for the two plates; the range of stress in each is determined by the external load and is the same as if the nip had not been introduced, but the total or maximum stress and, more particularly, the life depends both on the nip and on the external load.

The life of any leaf in a spring evidently depends both on the maximum stress to which it is submitted and on the " range " or the stress variation. From the theory, as developed above, we can calculate with accuracy both of these factors, and so in a similar manner we ought to be able to predict the life of each and every plate. It is the custom (at present) to consider the life of the spring, as a whole, to be that of the shortest life of any of the plates of which it is composed. The ideal spring would be the one in which all of the plates except the master plate had the same life, while for practical considerations the master plate had a life slightly in excess of the others. This last condition should prevail because the master leaf is the most important, it being the one which is directly connected to the vehicle. So long as the master leaf exists intact then the vehicle may run quite a distance with care and at slow speed, whereas if the master plate was fractured the car could not be run at all. (See Landau, United States Patent No. 1,199,013, issued September 19, 1916.)

ENDURANCE OF MATERIALS UNDER VARYING STRESS.

The question of the endurance of materials under fluctuating stress is of considerable practical and theoretical importance, but unfortunately up to the present time there has never been any satisfactory solution correlating the endurance and stress range relation; we have studied much of the available information, both old and new, without finding anything that will give a very definite answer to the question for our needs, which is, to predict the life when the stress variations are known. We have tried many of the existing formulæ and have carefully compared the results as given by them with the results obtained on the endurance testing machines, and as the result of our study we have found that for present purposes and, with the present state of our knowledge, the parabolic relation of Gerber, based on a study of Wöhler's tests on materials subjected to varying stresses, gives an answer more nearly in accordance with the observed facts than any of the other formulæ. Gerber's formula, however, does not succeed in giving the relative life of the various plates; it does appear to be able to predict with reasonable accuracy which of the plates will break the first—the curve of relative liability to breakage for the various plates composing a spring as given by the use of Gerber's relation is quite similar to that obtained by plotting the results of destruction tests on more than 500 springs—but the actual numerical relations are, however, still considerably in error. In the absence of more accurate information and with the present state of our knowledge we shall, for the time being, make use of the Gerber relation.

Gerber's formula is[4]

$$F = \frac{R}{2} + \sqrt{f^2 - nRf} \quad \text{.......... (56)}$$

in which

F = the maximum stress intensity
R = the range of stress
f = the ultimate static strength of the material, and
n = a constant to be determined from practice, = about 2 for hard steels.

The form in which this equation is given is not convenient for our purpose, and we have found it better to write

$$R = aF$$

where

$$a = \frac{\text{maximum stress} - \text{minimum stress}}{\text{maximum stress}}$$

we may then write

$$F = \frac{2f\left(\sqrt{n^2a^2 + (2-a)^2} - na\right)}{(2-a)^2} \quad \text{.......... (57)}$$

$$= \text{say } bf,$$

where b is a function of a and n (= 2) only.

The limits for a are evidently zero and 2, corresponding to static loads and to reversed loads of equal amounts respectively. For $a = 2$, equation (57) fails to give a direct answer, as it leads to the indeterminate form 0/0, but by referring to the original equation (56) it is at once seen that for this case $b = \frac{1}{2n}$, or ¼ for the hard steels.

In order to facilitate the application of this theory to plate springs, Table VIII has been calculated, giving the values of b corresponding to values of a varying by 0.02 for the complete range from 0 to 2.

We will now apply this to the Liberty B front spring. The nipping loads and the relations between the reactions and the external loads have already been given. The external load for which the spring was designed is 2000 lbs. With reference to the values of I and Z (the moment of inertia and the modulus for bending); the plates have rounded edges and are slightly concave, so that the values of I and Z are slightly less than they would be for rectangular plates.[5] A careful calculation shows that for the $3'' \times 5/16''$ plates $I = .006687$ and $Z = .04280$, while for the $3'' \times \frac{3}{8}''$ plates $I = .01169$ and $Z = .06236$.

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[4] See Unwin, "Elements of Machine Design." Vol. 1, Chapter II.

Making use of these figures, it will be found that the stresses and stress ranges for the different plates composing the spring are as follows:

n	*I*	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*
1	1133	491	642	.56	.679	1358	1.20	1.44
2	825	350	475	.58	.666	1332	1.62	1.07
3	660	238	422	.64	.635	1270	1.93	90
4	543	144	399	.74	.584	1168	2.15	.80
5	480	93	387	.80	.555	1110	2.31	.75
6	414	25	389	.94	.496	992	2.40	.72
7	320	−60	380	1.18	.412	824	2.58	.67
8	209	−168	377	1.80	.278	556	2.67	.65
9	249	−325	574	1.76	.284	568	1.75	.99
10	136	−438	574	1.30	.378	756	1.73	1.00

In the above table the column *n* is the number of the plate under consideration, counting from the shortest plate, which is called No. 1.

Column I is the stress due to both the nipping and the external loads in thousands of pounds per square inch.

Column II is the stress in thousands of pounds per square inch due to the nipping loads only.

Column III is the range of stress or the difference between *Column I* and *Column II* again in thousands of pounds per square inch.

Column IV is *a*, or the range of stress (*Column III*) divided by the maximum stress (*Column I* or *II* as the case may be).

Column V is *b*, as found from Table VIII for the corresponding value of *a*.

Column VI is the useful working stress (ultimate) as determined by multiplying the ultimate strength of the material, assumed to be 200,000 lbs. per square inch, by the corresponding *b* of *Column V*.

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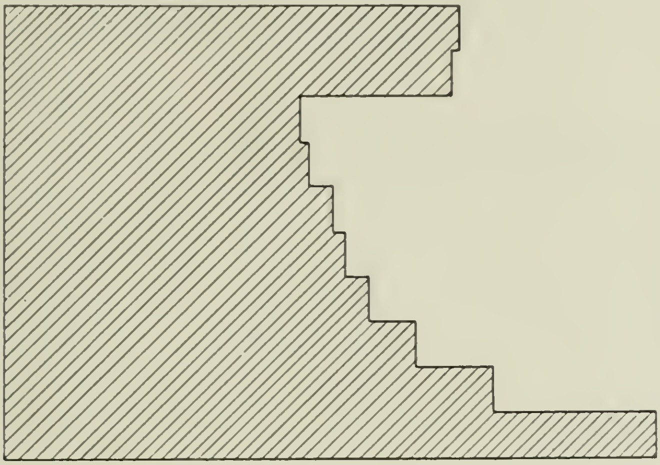
[5] We would draw attention to the fact that nearly all actual spring steel bars are rolled slightly concave in the thickness and with rounded edges, so that the moment of inertia I and the strength modulus Z are less than for a rectangular bar. The reduction is greater than is usually appreciated, being in the neighborhood of 10 per cent. on an average, and reaching 14 per cent. with some sections; for accurate results it is therefore necessary to use the true values of I and Z in our formulæ, and not to consider the section as rectangular, which may lead to very serious errors.

Column VII is the factor of safety, as determined by dividing the figures of *Column VI* by those of *I* or *II,* whichever may happen to be the greater.

Column VIII is the relative liability to fracture of the various plates, being proportional to the reciprocals of *Column VII,* according to the Gerber expression before mentioned. These are the most interesting since they give the relative probabilities of the breakage of the various plates when the liability of breakage of the master leaf is taken as unity.

FIG. 33.

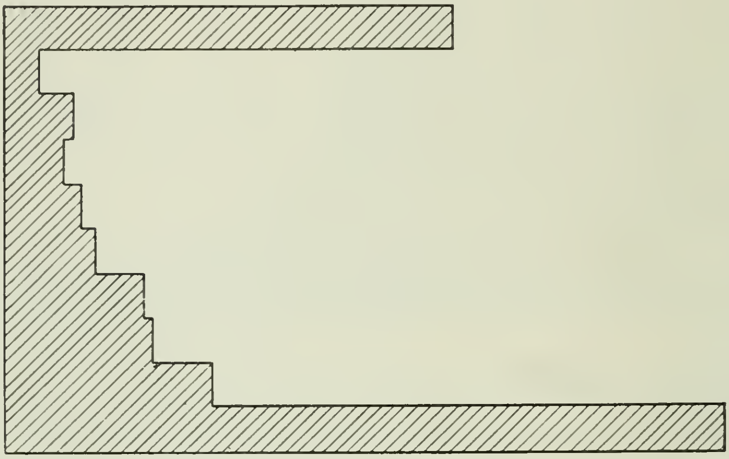


It is to be noticed that the stress variations and breakage liabilities as given above have been calculated for the case when the external load is alternately fully applied and completely removed. In actual operation the load fluctuation is usually from something under to something over the normal, with an occasional total removal, and even reversal, on the rebound after the wheels of the vehicle have encountered an obstacle: The relative lives of the different plates will be found to be different, according to the particular load variation adopted as the basis of calculation, but, on the whole, it will be similar to that obtained by taking the load variation as being from zero to full load alternately, and in the absence of absolute information as to the actual average variation we have made the calculations of the basis mentioned.

The results of the calculation are shown by Fig. 33, from which the relative liability to breakage is more readily appreciated than it is from looking at the table given above. It is seen that the short plate is by far the most likely to fracture, and also that there is a considerable liability for the master and the long plates to break. This is quite in accordance with the results of observations of other springs both on the endurance testing machines and in service.

Fig. 34 shows the average relative liability to breakage for the various plates of plate springs, as determined by a careful study of more than five hundred fractures. It will at once be noticed that the general form of the calculated liabilities as shown by Fig. 33 is quite similar to the observed liabilities as shown by Fig. 34, but that the middle plates do not, in practice, break with such frequency as would be indicated by the calculations. This is the justification for our earlier remark that the theory appears to give a fair idea as to which plate will break first and some idea of the relative liability, but that it does not give the relative liability to fracture with any great degree of accuracy. In the present state of knowledge regarding the effects of alternating stress on materials, this appears to be as far as it is possible to go; later on, when the question of alternating stresses has been further advanced by investigations now under way by others, we may expect to be able to predict with absolute certainty the relative liabilities to fracture of the various plates and to design springs which will be perhaps theoretically and practically perfect; in the meantime, we can say that our New Theory of Plate Springs is as perfect as present-day knowledge permits—especially that portion of it which deals with the question: "How long will any spring endure?" This phase of the problem is only an extension

FIG. 34.



of the general reasoning of our New Theory of Plate Springs which the second paper has so carefully expounded.

TABLE VIII.

$\frac{\text{Max.-min.}}{\text{max.}}$	Factor	$\frac{\text{Max.-min.}}{\text{max.}}$	Factor	$\frac{\text{Max.-min.}}{\text{max.}}$	Factor
.00	1.000	.70	.604	1.40	.353
.02	.990	.72	.594	1.42	.348
.04	.980	.74	.584	1.44	.343
.06	.969	.76	.574	1.46	.339
.08	.958	.78	.564	1.48	.335
.10	.948	.80	.555	1.50	.331
.12	.937	.82	.546	1.52	.327
.14	.926	.84	.537	1.54	.323
.16	.914	.86	.529	1.56	.319
.18	.902	.88	.520	1.58	.315
.20	.891	.90	.512	1.60	.311
.22	.879	.92	.504	1.62	.307
.24	.868	.94	.496	1.64	.303
.26	.856	.96	.488	1.66	.299
.28	.844	.98	.480	1.68	.296
.30	.832	1.00	.472	1.70	.293
.32	.821	1.02	.465	1.72	.290
.34	.809	1.04	.458	1.74	.287
.36	.797	1.06	.451	1.76	.284
.38	.784	1.08	.444	1.78	.281
.40	.772	1.10	.437	1.80	.278
.42	.760	1.12	.431	1.82	.275
.44	.749	1.14	.424	1.84	.272
.46	.737	1.15	.418	1.86	.269
.48	.725	1.18	.412	1.88	.266
.50	.714	1.20	.406	1.90	.263
.52	.703	1.22	.400	1.92	.260
.54	.691	1.24	.394	1.94	.257
.56	.679	1.26	.388	1.96	.254
.58	.666	1.28	.383	1.98	.252
.60	.656	1.30	.378	2.00	.250
.62	.646	1.40	.373		
.64	.635	1.42	.368		
.66	.625	1.44	.363		
.68	.614	1.46	3.58		

The Phenomena of Fluorescence. DESMOND GEOGHEGAN. (*Chemical News*, vol. 117, No. 3058, p. 322, October 11, 1918.)—Fluorescence was the name given by Stokes to designate certain phenomena which he observed when following up the investigations in the same subject of Herschel and Brewster. Stokes noticed that under certain conditions the rays of light are capable of undergoing a change of refrangibility. Herschel and Brewster had observed that some varieties of calcium fluoride (fluorspar), and also certain other substances when in solution, appeared colorless when looked at by transmitted light, but when viewed by reflected light presented an appearance which varied with the material used, being of a bluish color in some solutions and of a greenish color in others. Stokes found that this property, which as before stated he called fluorescence (on account of its having been first observed in fluorspar), is characteristic of a large number of substances other than fluorspar; thus if by means of a lens of long focus, preferably made of quartz, a line of the sun's rays be focussed on a solution of quinine sulphate, rendered more soluble by the addition of two drops of strong sulphuric acid, contained in a glass trough, a beautiful cerulean blue cone of light is formed which is much brighter on the surface and whose intensity rapidly diminishes as it penetrates the liquid.

It thus appears that fluorescence is due or is caused by the rendering visible to the eye of the ultra-violet rays. During the process of the invisible ultra-violet rays becoming visible, certain rays of the spectrum are necessarily absorbed. Thus rays of light which have passed through a sufficient thickness of a fluorescent substance lose thereby the power of exciting fluorescence when they are passed through a second layer of the same substance.

Power Requirements for Domestic Electrical Appliances. ANON. (*Motor Age*, vol. 34, No. 25, p. 9, December 19, 1918.)—The current needed by the usual devices is perfectly definite—and is given in the following table:

	Watts	Equal to
Fifty-candlepower lamps	40	2 lights
Water pump, 1/6 hp.	200	10 lights
Water pump, 1/2 hp.	600	30 lights
Air pump, 1/2 hp.	600	30 lights
Cream separator, 1/6 hp.	200	10 lights
Churn, 1/6 hp.	200	10 lights
Electric water heater	350	18 lights
Electric grill	500	25 lights
Electric stove	600	30 lights
Vacuum cleaner	160	8 lights
Washing machine	200	10 lights
Flat iron	600	30 lights
Electric toaster	525	26 lights
Fireless cooker	600	30 lights
Electric fan	75	4 lights
Warming pan	75	4 lights

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

A RELATION CONNECTING THE DERIVATIVES OF PHYSICAL QUANTITIES.[1]

By Mayo Dyer Hersey.

[ABSTRACT.]

In this paper it is shown how the theory of dimensions may be used in a differential form; a procedure which appears fruitful particularly in investigating the effect of given sources of error on the performance of measuring instruments.

The examples which led to the necessity for developing this method are discussed at the end of the paper and illustrated by experimental data.

NEW BAUMÉ SCALE FOR SUGAR SOLUTIONS.[2]

By Frederick Bates and H. W. Bearce.

[ABSTRACT.]

Many different Baumé Scales have been proposed and used in the past. At the present time there are still in use in the United States three different scales for liquids heavier than water. Two of these, namely the " Holland " scale and the " Gerlach " scale are used in sugar work. Neither is adapted to modern requirements. The new table lies between the " Holland " and " Gerlach " scales and has three important advantages which should commend it for general use. They are:

1. It is based upon the specific gravity values of Plato, which are considered the most reliable of any available.

2. It is based on 20° C., the most convenient and widely accepted temperature for sugar work.

3. It is based on the modulus 145, which has already been adopted by the Manufacturing Chemists' Association of the United States, by the Bureau of Standards and by all American manufacturers of hydrometers.

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* Communicated by the Director.

[1] Scientific Papers of the Bureau of Standards No. 331.

[2] Technologic Paper, No. 115.

SOLDERS FOR ALUMINUM.[3]

[ABSTRACT.]

The use, serviceability, method of application and composition of solders for aluminum are discussed in the light both of special tests made at the Bureau on commercial and other compositions of solders and of general experience with them. All soldered joints are subject to rapid corrosion and disintegration and are not recommended except where protection from corrosion is provided. Suitable compositions for solders are obtained by the use of tin with addition of zinc or both zinc and aluminum within wide percentage limits.

A CRITICAL STUDY OF THE LEDEBUR METHOD FOR DETERMINING OXYGEN IN IRON AND STEEL.[4]

By J. R. Cain and E. Pettijohn.

[ABSTRACT.]

Errors in the method and their remedies are discussed. Special methods for preparing samples are given and new forms of apparatus are described. The metallurgical significance of the results obtained by the Ledebur Method is pointed out. It is shown that "(*a*) The Ledebur method requires extraordinary precautions to obtain reliable results. The errors we have described undoubtedly affect in greater or less degree nearly all results by this method that have been described in the literature, and if these are approximately correct it is because of compensation errors; (*b*) The Ledebur Method as described determines with certainty only oxide of iron, oxides of manganese above Mn, and the oxides of nickel, copper, and tungsten if the latter three ever exist in steel. In turn such oxides are determined correctly only in case they exist in the metal uncombined as silicates which probably seldom happens; (*c*) Ledebur oxygen determinations show no distinguishing features for acid Bessemer, basis or acid open-hearth, duplex, electric furnace or crucible steel; (*d*) Ledebur oxygen determinations show no differences in steels deoxidized with a variety of deoxidizers."

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[3] Bureau of Standards Circular No. 78.

[4] Technologic Papers, No. 118.

TESTS FOR HOLLOW BUILDING TILES.[5]

By Bernard D. Hathcock and Edward Skillman.

[ABSTRACT.]

Introduction.—Originally hollow building tile was used mostly for its fire-resisting properties, but, as its other advantages have become more generally recognized, its range of usefulness has been greatly broadened until to-day it is an important structural material. And, as a consequence of the rapid growth of its use and the relative lack of definite and reliable information of its strength, these tests have been made by the Bureau of Standards.

Tiles are molded of clays which are quite diversified in their properties, and, after drying, are burned in downdraft kilns at a temperature well beyond initial vitrification of the clay, but rarely high enough to complete vitrification. These methods introduce variables, especially of color and porosity, which are of great importance because of their relation to the strength properties of the tiles, and have been given consideration in the classification of the tiles of these tests. It is a well-known fact that in a downdraft kiln the upper courses of the tiles are heated to a higher temperature than the lower ones. This gives the top tile a higher degree of burning, those near mid-height a medium degree of burning, those near the bottom a low degree of burning. In general, the high burned tiles are dark in color, the medium burned of medium shade, and the low burned light. However, this is not always true, for the natural color of some clays or the presence of coloring matter will cause a variation.

Scope of the Tests.—The tests of this paper are limited to those of compression and absorption. The total number of those performed is approximately 250, of which the majority were upon tiles in compression. Stress-strain readings were taken upon 114 of these for modulus of elasticity determinations. About 70 absorption tests were made upon samples taken from tiles previously tested in compression. All the tiles were graded according to their color, as dark, medium, or light corresponding to the variations produced as described above. The tiles tested were made with few exceptions from clay of the buff burning variety, and the colors given indicate variations in the buff color.

Method of Tests.—Previous to testing the tiles, their sectional areas and weights were determined. The former was done by measuring the walls and partitions with calipers and computing the sectional area from these measurements. Then they were capped with plaster of Paris to insure a uniform bearing in the testing machine. Small brass plugs were also set in some of the tiles for compressometer readings. The type of compressometer used was the 8-inch Berry strain guage, and readings were taken with it near the four corners of every tile upon which stress-strain relations were desired. The testing machines used were of the Olsen universal type.

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[5] Technologic Papers No. 120.

The absorption tests were made upon three samples selected from each tile upon which the absorption determination was desired. The tiles from which these samples were taken had been previously tested in compression.

Results.—The results of the compression tests with moduli determinations show that the strain produced by loading a tile is approximately a linear function of the applied load until failure is approached, or in other words, the modulus of elasticity of a tile is practically constant until failure. This indicates also that there is no definite proportional limit for tile; that is, the proportional limit is coincident with failure.

Tiles were tested on end, on edge and flat, and the results show that in general a tile develops both the greatest unit strength and greatest total strength when it is laid on end. The relation between the moduli of elasticity of tiles and their compressive strengths is somewhat variable, or the tile having the highest modulus of elasticity may not have the greatest strength, but in general if the modulus is high, it is to be expected that the compressive strength will also be relatively high.

There was found to be no definite relation between the loads at the incipient failure and the maximum loads sustained by the tiles. In some cases the incipient failure occurred early in the tests, but in other tests no notice of failure was observed until the maximum loads were reached.

There is shown to be a relationship existing between the colors of the tiles and their compressive strengths and the moduli of elasticity. The dark and medium burned tiles have about the same relative compressive strengths and moduli of elasticity, while the same properties of light burned tiles are on an average much lower.

From the results of the absorption tests it was found that the maximum compressive strengths vary approximately inversely with the percentages of absorption. Also the percentages of absorption of the tiles vary with their colors. In general, the darker the tiles the lower the percentages of absorption are likely to be, but this is not always true because either the material or the artificial color of the tiles may often be deceptive in this respect.

THE TABLE OF UNIT DISPLACEMENT OF COMMODITIES.[6]

By Harry M. Roeser and Lillie E. Johnson.

[ABSTRACT.]

THIS circular showing (1) the number of pounds per cubic foot as packed for shipment, (2) the number of cubic feet of space required for a short ton, (3) the number of cubic feet of space required for a long ton, and (4) the manner in which the material is packed, lists several hundred commercial commodities alphabetically. Appendixes give special information concerning automobiles, canned fruits and vegetables, and fresh fruits and vegetables.

This table has been prepared to meet an immediate demand for such information and will be revised and augmented from time to time as further data is obtained. The Bureau will, therefore, be pleased to receive information, criticism, and suggestions from those interested in the table.

ELECTRICAL OSCILLATIONS IN ANTENNÆ AND INDUCTANCE COILS.[7]

By John M. Miller.

[ABSTRACT.]

THE mathematical theory of circuits having uniformly distributed electrical characteristics such as cables, telephone lines and transmission lines is applied to the oscillations in antennæ and inductance coils.

It is shown how the frequency of the natural oscillations of an antenna may be determined analytically or graphically when inductance coils or condensers are inserted in the lead-in. Expres-

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[6] Circular No. 77.

[7] Scientific Papers No. 326.

sions are derived which permit the calculation of the effective resistance, inductance and capacity of the antenna, and it is shown that in so far as frequency or wave length computations are concerned the simple formula applicable to ordinary circuits with lumped constants gives very accurate results. Experimental methods are given for determining the effective and static or low frequency values of the antenna constants.

Inductance coils are likewise treated from the standpoint of the theory of distributed characteristics. Expressions are obtained for the reactance of the coil at any frequency and for the natural oscillations of a circuit of coil and condenser. It is further shown that, in so far as the frequency of oscillation is concerned, an inductance coil with distributed characteristics is equivalent to a pure inductance of constant value with a constant capacity across its terminals. Excepting for skin effect, this pure inductance would be the same as the low frequency inductance of the coil. This explains a fact which has been frequently observed experimentally, in particular for single layer solenoids.

TOLUOL RECOVERY.[8]

By R. S. McBride, C. E. Reinicker, and W. A. Dunkley.

THE importance of high explosives in the present war has been amply demonstrated. Nearly all types of explosives are used in some way, but trinitrotoluol, commonly known as T.N.T., because of its high power and great stability, is one of the preferred explosives. As an important constituent in shells T.N.T. is used both alone and mixed with other explosives. Especially for naval use it is used alone, because the greater stability permits longer storage of the shells before use. On account of the great demand for T.N.T. there has grown up also a large demand for those materials from which it is made, especially toluol. This material finds numerous applications in the chemical industries, but particularly it has been used in the manufacture of dye-stuffs and for the preparation of T.N.T. For this latter it is only necessary to treat the toluol with nitric acid under proper conditions in order to produce the explosive, which is then refined by appropriate means to such degree of purity as is required for the use for which it is intended.

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[8] Technologic Papers No. 117.

THE COMPRESSIVE STRENGTH OF LARGE BRICK PIERS.[9]

By J. G. Bragg.

[ABSTRACT.]

THE following is an abstract of the report on tests of large brick piers which were made at the Pittsburgh laboratory of the Bureau of Standards in coöperation with the National Brick Manufacturers Association.

The purpose of this investigation was to determine the strength developed by brick piers of normal size as used in modern buildings, using in their construction such materials and grades of workmanship as are available in the United States.

The variables considered in the investigation are: (1) the quality of bricks employed with respect to grade and geographical location; (2) the quality and kind of mortar; (3) the grade of workmanship employed, and (4) the bonding of courses or method of laying the bricks.

The investigation comprises tests on forty-six piers 30″ × 30″ × 10′ in height, also four piers of the same cross sectional dimensions 5′ in height. The bricks used in their construction are representative of four widely separated districts east of the Mississippi River and are classified according to the following three grades:

Grade 1.	Hard burned or best quality.
Grade 2.	Medium burned or considered as common.
Grade 3.	Soft burned or poorest product marketed.

Three mortars were used in the beginning and three grades of bond and workmanship were employed throughout the investigation.

The mortars used were:

1. 1 part cement, 3 parts sand by weight.
2. 1 part lime, 6 parts sand by weight.
3. 1 part $\left\{\begin{matrix}\text{15 per cent. lime}\\ \text{85 per cent. cement}\end{matrix}\right\}$, 3 parts sand by weight.

The different methods of bonding are as follows:

1. Alternating header and stretcher courses.
2. Header course every 4th course.
3. Header course every 7th course.

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[9] Technologic Papers No. 111.

Wire mesh was used in two of the 8-foot piers to study the effect of lateral reinforcing in the horizontal joints. A more than usual number of tests of individual bricks were made in order to determine the relation of the strength of single bricks to the compressive strength of piers.

Results.—The first indication of failure observed was the same in all cases and appeared in the form of small hair sized cracks in the individual bricks. The cracks widened and extended to other courses under additional load, finally becoming confluent and extending almost the entire length of the pier. Soon thereafter final failure occurred accompanied by a spawling off of the outer ring of bricks. Very little crushing of the bricks was apparent after failure except in the case of the softer bricks laid in cement or cement-lime mortars. The cause of incipient failure of the piers is attributed to a transverse failure of the individual bricks.

The tests show that variations in the number of header courses used does not effect the ultimate compressive strength of the pier. Failure of the individual bricks by fluxure would render the header courses ineffective by such time as they would be useful in preventing an outward bulging of the masonry.

The quality of bricks is shown to be a very important factor in its effect on the compressive strength of the pier. The compressive strength of half bricks flat and one edge, also the transverse strength or moduli of rupture of the bricks are shown to be proportional to the compressive strength of the piers.

Very little difference in strength is apparent in piers of 1:3 Portland cement and sand mortar and those of 1 (15 per cent. lime and 85 per cent. cement) :3 sand mortar. In the last named mortar 35 per cent. by volume of the cement is replaced by lime. These piers of cement and cement-lime mortars, however, developed strengths 50 per cent. to 75 per cent. higher than those of pure lime mortar. There is a considerable advantage in the easier working qualities of the cement-lime mortar over the pure Portland cement mortar. In consideration of the results of these and previous tests on piers of smaller cross sectional dimensions, from 25 per cent. to 50 per cent. of the cement in a 1:3 cement mortar may be replaced by hydrated lime without appreciably affecting the compressive strength of the masonry; the higher percentage to be used in piers of small cross sectional dimensions.

A study of these and previous tests indicate that lateral reinforcing in the horizontal joints is effective only when placed in every joint.

The following empirical formulas are given for use in computing the strength of brick piers:

1. $P = K\,p$
2. $P = K\,R$ where

P = the ultimate unit compressive strength of the pier,
p = the unit compressive strength of single half bricks,
R = the unit transverse strength or modulus of rupture of single bricks,
K = is a constant depending upon the kind of mortar used.

The values of K are given as follows for the mortars used in this investigation:

Mortar	Values to be determined by tests of single Bricks	Value of K
1 { 15 per cent. lime 85 per cent. cement }	Unit compressive strength flat $= P$	.26
to 3 parts sand	Unit compressive strength on edge $= p$	.30
by weight.	Modulus of rupture from transverse test $= R$	1.25
1 part lime	Unit compressive strength flat $= P$	.11
to	Unit compressive strength on edge $= p$	.14
3 parts sand	Modulus of rupture from transverse test $= R$	.65
1 part cement	Unit compressive strength flat $= P$	.27
to	Unit compressive strength on edge $= p$	.32
3 parts sand	Modulus of rupture from transverse test $= R$	1.45

The modulus of rupture is computed according to the formula:

$$R = \frac{3\,P\,l}{2\,b\,d_2}$$ in which,

R = the modulus of rupture,
P = the breaking load, in pounds, of a single brick in a flatwise position supported at the ends and loaded at the centre.
l = the distance between the supports (in these tests 7 inches),
b = the breadth of specimen in inches,
d = the depth of specimen in inches.

The complete report includes twenty-four figures and numerous tables. There is also a chapter devoted to previous tests giving abstracts and tables of the results from previous investigations of the load bearing values of brick piers.

Industrial Alcohol. ANON. (*The* (London) *Times Engineering Supplement,* vol. 14, No. 529, p. 228, November, 1918.)—In Great Britain, at present, alcohol is mainly obtained by fermentation processes from grain together with small quantities by distillation of molasses. In Germany, production from potatoes by a combined hydrolytic and fermentation process has been largely used to supplement the grain fermentation process. The first stage in the operation consists in the conversion, by treatment with acids, of the starch content of the potato into glucose, which is then fermented to yield the alcohol desired. Among other possible sources, attention has been directed to the utilization of wood waste, and to the synthetic production of alcohol from calcium carbide.

The principal constituent of wood is the complex carbohydrate commonly known as cellulose, and this is available in abundant quantities in the wood waste obtained in the operations of the timber trade. The problem of recovering alcohol from such material consists in the conversion, by disintegration, of the cellulose constituent of the wood into fermentable sugars from which alcohol can be readily obtained. The possibility of effecting such a conversion has been known for more than a century, and many attempts at commercial realization of the project have been made. It is only recently, however, that success has become practicable, largely owing to detailed study of the problem by the lumber interests in North America stimulated by the assistance of Government investigation, such, for example, as that conducted by the United States Forest Products Laboratory at Madison, Wisconsin. As to yields obtained, 20 to 22 per cent. of the dry wood is fermentable sugar. This corresponds to 35 gallons of 95 per cent. spirit per ton of dry wood. Thus far, in actual practice, the yields have scarcely exceeded 20 gallons per ton, as contrasted with a yield of 80 gallons per ton from corn.

To a country such as Great Britain with no considerable timber areas, the synthetic process of alcohol manufacture must be of prime consideration. As developed hitherto, calcium carbide is the starting point of the synthesis, a fact which suggests the necessity of cheap power production. By treatment of the carbide with water, acetylene gas is obtained, and this on reaction in presence of a catalytic material is converted into acetaldehyde. From the latter, by a further process of catalytic reduction, alcohol results. The production of alcohol from acetaldehyde does not exhaust the possibilities of synthetic processes. Large scale production of ethylene hydro-carbons would lead to the development of a synthesis by direct hydration from which alcohol would result in a one-stage operation.

NOTES FROM NELA RESEARCH LABORATORY.*

THE INFLUENCE OF TEMPERATURE ON THE TRANSMISSION-FACTOR OF COLORED GLASSES.

By M. Luckiesh.

THERE are numerous gaps in our knowledge of the physics and chemistry of colored glasses which either have not been spanned at all or have been flimsily bridged by theory supported more or less by inadequate experimental data. On the other hand, a number of investigators have made excellent contributions which indicate that light may be shed on some of the questions by physical data of various kinds. Hyde, Cady, and Forsythe, in studying red pyrometer glasses, noted the influence of temperature on the transmission characteristic of a red glass and investigated this influence for temperatures of 20° C. and 80° C. The transmission-factor of the red glass is appreciably less for various wave-lengths at the higher temperature than at the lower temperature.

It appeared of interest to study this aspect with a number of commercial colored glasses and later to carry the work further with glasses especially made for the purpose. Only the transmission-factor for total visible radiation has been considered so far, but an idea of the change in spectral transmission may be gained by noting the change in color of the heated specimen. A given specimen was cut into two pieces and one was kept at room temperature, while the temperature of the other was increased gradually to 350° C. The relative transmission-factors of the two specimens were measured throughout this range, and a few of the results are presented in the table. No color-difference was encountered during the measurements except that due to a change in the spectral transmission characteristic of the heated specimen. This color-difference became very marked for specimens 5 and 10 at temperatures above 100° C. No analyses of the glasses have been made in this preliminary work. The color of the hot specimen is given as compared with that of the cold

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* Communicated by the Director.

Specimen	Principal coloring element	Color		Relative transmission-factors at various temperatures (centigrade)				
		Cold	Hot	30°	100°	200°	300°	350°
1	Copper....	Medium red....	....	100	97	92	87	84
2	Cobalt.....	Light blue......	....	100	101	104	107	108
3	Cobalt.....	Deep violet.....	Deep blue...	No appreciable change.				
4	Gold.......	Pink...........	Violet.......	100	99	96	94	93
5	Copper....	Blue-green......	Yellow-green	100	98	94	87	82
6	Manganese.	Purple.........	Blue-violet...	100	97	94	91	90
7	....	Lemon yellow...	Orange......	100	94	84	75	71
8	....	Dull yellow.....	....	100	98	94	91	90
9	Copper....	Deep red.......	....	100	86	67	50	42
10	Chromium.	Yellowish green.	Yellow......	100	95	84	72	67

specimen in each case where a change was appreciable. All the glasses, except the two containing cobalt, decreased in transmission-factor as the temperature increased. The curves obtained by plotting temperature and transmission-factor are approximately straight lines with the exception of that for specimen 5. Owing to the slow change in hue in the red end of the spectrum the red glasses, 1 and 5, did not change appreciably in color when heated, notwithstanding large decreases in their transmission-factors.

Aluminum Alloys. Anon. (*The Chemical Trade Journal and Chemical Engineer,* vol. 63, No. 1647, p. 446, December 14, 1918.)—Aluminum was merely a scientific curiosity a generation ago, the production in 1883 having been but 83 pounds; but it is now one of the most common metals in use, with an annual production of hundreds of thousands of tons. It is most important in its alloys, especially in those with magnesium and copper. The alloy known as magnalium is a series of mixtures containing 10 to 30 per cent. of magnesium; it is silver-white in appearance, strong, ductile, easily cast, takes a fine polish, and has a specific gravity of only 2 to 2.5, somewhat less than that of aluminum itself. With 10 per cent. of magnesium the melting-point is between 650° and 700° C. The metal is made harder, more brittle and finer in polish by additions of magnesium up to the practical limit of 30 per cent.; it may be given a dark color by maceration, or it may be nickelled or gilded. Duralumin, with 3.5 to 5.5 per cent. of copper and about 0.5 per cent. each of magnesium and manganese, has greater hardness, tensile strength and polish, and may be easily hardened, but it is given special value by its resistance to the action of sea water and dilute acids. It is a little heavier than aluminum, with a specific gravity of about 2.8. Other alloys, similar to magnalium, but adapted to special uses, contain small percentages of nickel, tin, lead and iron.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE RETICULATION OF GELATINE.[1]

By S. E. Sheppard and F. A. Elliott.

[ABSTRACT.]

The production of reticulation is ascribed to localized release of normal, *i.e.*, lateral, swelling of the gelatine layer on plate or film. Normally the gelatine layer swells and shrinks almost entirely in the direction perpendicular to the support. If it is treated with reagents (or under conditions of temperature) so that an excessive swelling is produced, it may strip off the plate. If the excessive pressure is restrained by tanning agents, it may easily happen that the restraint is not uniform; that is, we do not have at every point exactly compensating amounts of the swelling substances and the tanning reagent, but accumulation of one at one point, and accumulation of the other at an adjacent point. In consequence, we get a localized excessive swelling and shrinkage adjacent to each other, the net result of which is the reticulation pattern. At the same time, if developed silver grains are present in the film, these aggregate in the more swollen portions, leaving the less swollen parts poorer in silver. It is pointed out that excessive "graininess" in developed images is very probably due to incipient or latent reticulation, because the products of development are tanning substances which will tend to be retained by the silver as reduced; photographs and curves illustrating these results are given.

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* Communicated by the Director.

[1] Communication No. 71 from the Research Laboratory of the Eastman Kodak Company, published in *J. Ind. and Eng. Chem.*, Oct., 1918, p. 727; *Studio Light,* Sept., 1918, p. 8.

Domestic Fuel Saving. ANON. (*The* (London) *Times Engineering Supplement*, vol. 14, No. 529, p. 229, November, 1918.)—The problem of heating a house or room by the combustion of solid or gaseous fuel, without waste, is far more difficult of solution than that of heating water in a steam boiler or materials in a furnace, and whereas the thermal efficiency of industrial heating apparatus ranges from 50 to 70 per cent., the average efficiency of domestic heating appliances is probably less than half this figure. This large difference is due to the fact that, for heating rooms and houses in this country (England), radiant heat is chiefly utilized; and that the ordinary old-fashioned type of firegrate is a most inefficient apparatus for producing radiant heat, or even for obtaining proper combustion of all the constituents of the fuel. In England there is a rooted objection to any system of heating that produces "stuffiness," or hinders the free and rapid movement of air, and with all its defects, the British system of heating rooms provides excellent ventilation. It is this fact that has saved the old-fashioned type of firegrate from long ago having been discarded.

In regard to the combustion of fuel, the aim is to produce as much radiant heat as possible, and to reduce the losses of heat by convection and conduction to the lowest possible limit. A red glowing surface of coal or coke is one of the best of heat radiators, and a small bright fire is, therefore, much more efficient for heating a room than a much larger one that has been permitted to become dull and lifeless. Another objection to the latter is that, when fresh coal is added, the temperature is generally too low to ignite the volatile constituents of the coal; the larger portion of these gases, therefore, escape up the chimney unburnt, and not only contaminate the atmosphere with tarry vapors, but carry with them one-third of the calorific value of the fuel absolutely unused. To allow a fire to fall into this dead state and then add fresh fuel before reviving it, is most wasteful, although nine out of ten persons do not realize the fact. The most practical and scientific method of saving coal in the heating of rooms by open fire-grates is always to maintain a bright glowing fire, and to add fresh fuel a little at a time, but often enough to maintain the fire at the original size.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE COLOR LABORATORY OF THE BUREAU OF CHEMISTRY. A BRIEF STATEMENT OF ITS OBJECTS AND PROBLEMS.[1]

By H. D. Gibbs.

[ABSTRACT.]

ABOUT two years ago the color work of the Bureau of Chemistry, formerly confined to the solution of problems arising from the enforcement of the Food and Drugs Act, was organized and extended to include questions pertaining to the manufacture and utilization of colors. The new plan provided for laboratory investigation of natural and artificial colors, as well as for the reproduction of laboratory processes on a technical scale.

The aim of the laboratory studies, which so far naturally have predominated over the plant studies, has been to develop processes which can withstand competition, a goal best reached by investigating conditions underlying yields and costs. These studies may be divided into five classes: (1) *Processes,* such as chlorination, sulphonation, oxidation, and sublimation; (2) *dye intermediates,* comprising phthalic anhydride, H-acid, a large number of sulphonic-acid derivatives of naphthalene, benzene, toluene, and cymene, together with the chlorin compounds of toluene and cymene, and a number of the quinolines; (3) *dyes,* including malachite green, the sulphonephthaleine, cymene dyes, dyes for sensitizing gelatine emulsions of the silver halides, and several biological dyes; (4) *medicinals;* and (5) *analytical methods* for handling the products. Papers on the analytical methods devised have appeared in the *Journal of Industrial and Engineering Chemistry* (1918), vol. 10, pages 425, 436, and 453, in the *Journal of the American Chemical Society* (1918), vol. 40, pages 1443, 1449, and 1453, and in the *Journal of the Washington Academy of Sciences* (1918), vol. 8.

Several large-scale operations have also been attempted. In coöperation with various manufacturers, the development of a

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* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Ind. Eng. Chem.,* 10, 1918, p. 802.

process for the manufacture of phthalic anhydride has been studied. Plant investigations on the chlorination of toluene and the manufacture of various alcohols and acetone are now in progress.

As a result of the work done by the Color Laboratory, twelve patents have been dedicated to the people, and applications for a number of new patents are pending.

CERTAIN RELATIONS BETWEEN CRYSTALLINE FORM, CHEMICAL CONSTITUTION AND OPTICAL PROPERTIES IN ORGANIC COMPOUNDS.[2]

By Edgar T. Wherry.

In previous work on the refractivity of crystalline substances the mean refractive index has usually been employed. It seemed, however, desirable to inquire into the possibility of correlating the several indices of a given substance with its crystal structure, instead of concealing in mean indices whatever relations may exist. The Lorentz-Lorenz expression, $\frac{n^2-1}{n^2+2} - \frac{M \times \rho}{W}$, is most satisfactory, and for short the left-hand term is referred to as the "refraction" and denoted by the letter R. If the refractive indices in different directions in a single anisotropic substance be substituted for n, directional values of R, called R_a, R_b, and R_c, will be obtained, the first two being identical in uniaxial crystals. The atomic weight (W) being always, and the refractivity (M) usually, the same throughout the several values of R must be proportional to those of the density (ρ), or factors corresponding to it, in the several directions. The ratio of the R's, which may be termed the "refraction ratio," should therefore give some information as to the structure of the substance. The phenomenon of dispersion of double refraction renders the refraction ratio variable with the wave-length of the light, but calculation in some typical cases shows that the variation rarely exceeds 3 units in the third decimal place over the visible spectrum, so this may be ignored.

The spacings between the planes passing through the centres of gravity of the atoms in crystals are connected with the crystallographic axial ratios. The less the spacing of the planes in any direction in an anisotropic substance, the greater should be the refraction in that direction. If the layers are all close-packed, the factor ρ may be inversely proportional to the spacing *d,* and there should be an exact inverse relation between refraction ratio and crystallographic axial ratio, at least in cases where there are no serious disturbing factors. The work reported is limited to the tetragonal system. The crystallographic axial ratio usually adopted is not necessarily the one related to the optical properties, the alternate ratio or even the mean between the usual and the alternate being of significance in some cases.

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[2] Published in *Journal Washington Academy Sciences,* Vol. 8, pp. 277–285, and 319–327, May 4 and 19, 1918.

In urea, $CO(NH_2)_2$, the axial ratio, *c/a,* is 0.833, and the refraction ratio, R_ω R_ϵ is 0.834, the inverse proportionality being exact. A possible space-lattice for the substance, worked out on this basis, is found to agree with a variety of data, in particular with the atomic diameters of the elements present. In pentaerythrite a similar relation exists, but the composition is so complicated that only a suggestion of the structure can be given. In mellite the facts are similar, provided that the alternate axial ratio is taken. The double propionate group, of the metals *Ca, Sr, Ba,* and *Pb,* also shows interesting relationships of the same type. Several exceptions are noted, in which no proportionality between the two kinds of ratios appears to exist, but it can be shown that there are disturbing factors, such as intense coloration and asymmetric carbon atoms, present, so that the general rule of inverse proportionality may be regarded as generally applicable. Preliminary results with crystals of other systems are announced.

AMERICAN SUMAC: A VALUABLE TANNING MATERIAL AND DYESTUFF.[3]

By F. P. Veitch and J. S. Rogers.

[ABSTRACT.]

Sumac grows wild and abundantly on uncultivated lands in certain areas of North America, in quantities more than sufficient to tan all the light leather made in this country, if need be. At present large amounts of sumac are allowed to remain ungathered each year, while vegetable tanning materials of similar nature are quite extensively imported. This native tanning and dyeing material should be more completely utilized, and also improved in quality to serve as a check on the rising cost of like tanning and dyeing materials, to lessen our dependence on foreign countries, and to give the country people in certain sections an additional source of employment. The important tannin bearing species of sumac indigenous to North America may be readily recognized.

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[3] U. S. Department of Agriculture Bulletin 706.

Analyses of a large number of samples gave for the leaves and leaf stems the following average tannin content: Dwarf sumac (*Rhus copallina*), 28.95 per cent.; white sumac (*Rhus glabra*), 25.14 per cent.; staghorn sumac (*Rhus hirta*), 27.66 per cent. The tannin content of the stalks was found to be 7.77 per cent., 6.84 per cent., and 7.07 per cent., respectively.

An estimate by the Bureau of Chemistry gave a calculated yield from thick uniform stents of 4864 pounds green weight, or 1621 pounds cured, of sumac to the acre. In no case should an able-bodied man be satisfied with less than 200 pounds of cured sumac for his day's work. The total loss in weight of the mixed sumac leaf and stalks from gathering until it reaches the extract maker probably averages very close to 60 per cent. The extracted sumac has some value as a fertilizer for use on land deficient in organic matter.

Among the directions for proper gathering and curing are the following important points: Collect, preferably, only leaves and leaf stems; avoid red and yellow leaves; harvest from June to September, inclusive; do not unduly expose the gathered leaves to the sun; keep them from getting wet from rain or dew; do not pile the green sumac in layers over 1½ feet deep, and turn it frequently during drying to prevent heating and molding.

Properly gathered and cured domestic sumac leaves contain practically as much tannin as the imported Silician sumac, and will yield an extract much better in color and quality than that obtained from the domestic sumac as generally prepared at present for market. An appeal is made for coöperation between gatherers, dealers, and extract makers, with a view to producing not only more domestic sumac but also sumac of excellent quality.

THE FRANKLIN INSTITUTE.

(Proceedings of the Annual Meeting held Wednesday, January 15, 1919.)

Hall of The Franklin Institute,
Philadelphia, January 15, 1919.

President Dr. Walton Clark *in the Chair.*

Additions to membership since last report, 2.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The tellers of the election, Messrs. Jennings, Colvin, and Picolet, submitted the report of the ballots cast for President, Vice-President, Treasurer, and members of the Board of Managers, and the following gentlemen were declared duly elected to the respective offices:

Walton Clark, President (to serve one year).

Henry Howson, Vice-President (to serve three years).

Cyrus Borgner, Treasurer (to serve one year).

Francis T. Chambers, W. C. L. Eglin, Alfred C. Harrison, Nathan Hayward, Charles A. Hexamer, Robert W. Lesley, Marshall S. Morgan, and E. H. Sanborn, Managers (to serve three years).

The President presented a statement of the work of the Institute for the fiscal year ending September 30, 1918, with the reports of the various committees of the Institute and Board of Managers.

The paper of the evening was presented by A. Russell Bond, B.A., Managing Editor of the *Scientific American,* New York City, N. Y., entitled "Deep Sea Salvage After the War." An account was given of the damage done by the German undersea boats since August, 1914, it being estimated that about fifteen million tons of allied and neutral shipping had been sunk during the continuance of the war. Mention was made of the plans of Germany and the Allies in connection with the salvage work in deep water where ordinary methods would be ineffective. New apparatus devised by the Germans, as well as our own methods for recovering ships sunk in deep water, were described. The subject was illustrated by numerous lantern slides. Messrs. Eldridge, Henderson, the Secretary, and others participated in the brief discussion which followed the reading of the paper.

A vote of thanks was extended to the speaker for his interesting paper, and the thanks of the Institute were also conveyed to the tellers of the election for their services.

Adjourned.

George A. Hoadley,
Acting Secretary.

MEMBERS OF THE FRANKLIN INSTITUTE WHO ARE IN THE ACTIVE MILITARY OR NAVAL SERVICE OF THE UNITED STATES GOVERNMENT.

Name and rank	Branch of service	Location
Allen, Henry B., Captain	Ordnance Dept., N. A.	France
Amram, Philip W., 2nd Lieut.	Student Army Training Corps	Harvard Univ.
Anderson, Geo. L., Colonel	Board of Ordnance & Fortification	Washington
Atherholt, Gordon Meade	Aeronautical Mechanical Engineer, Signal Corps	Washington
Atterbury, W. W., Brig. Gen.	Director-General of Railways	France
Bacon, Raymond Foss, Lt. Col.	Head of Chemical Service Section, U.S.N.A.	France
Barnhart, G. Edw.	Aeronautical Mechanical Engineer, Signal Corps	Fairfield, Ohio
Barr, John H., Major	Ordnance Reserve Corps	Washington
Barrett, C. D., Major	9th Engineers	
Bartow, Edward, Major	U.S.N.A. Sanitary Corps	France
Billings, A. W. K., Lieut. Com.	Chief Engineer, U. S Naval Forces (Aviation)	London
Booz, Horace Corey, Colonel	Railroad Transportation Corps, U.S.N.A.	France
Bostwick, John Vaughan, Capt.	O.R.C., 315th Infantry	
Breed, George, Lieutenant	Fleet Naval Reserve, U.S.N.R.F.	New York
Brown, Lucius P., Captain	Sanitary Corps, Division of Food and Nutrition	Camp Greenleaf
Bunting, C. M., Colonel	E.O.R.C., U.S.A.	France
Cadwalader, Governeur, Major	Ordnance Dept., U.S.R.	
Caldwell, E. W.	Medical Officers' Reserve Corps	
Capps, W. L., Rear Admiral	Chief Constructor, U.S.N., Bureau of Construction and Repair	Washington
Carty, John J., Colonel	Signal Corps, U.S.A.	
Cathcart, Wm. L., Lieut. Com.	U. S. N. R. F.	Washington
Chance, Edwin M., Major	Chemical Warfare Service, N. A.	Baltimore
Clark, Beauvais, Sergeant	108th Field Artillery	France
Clark, E. B., Major	Gas and Flame Service, A.E.F.	France
Clark, E. L., 1st Lieut.	Signal Corps, 401st Telegraph Battalion	Camp Devens
Clark, Theobald F., Capt.	Field Artillery	France
Clark, Walton, Jr., Capt.	Field Artillery	France
Coates, Jesse, Major	American Expeditionary Force	France
Cope, Thomas D., Captain	Air Service, U .S. A.	Langley Field
Cornelius, John C., 1st Lieut.	Coast Artillery, U.S.N.A., 13th Company	Sandy Hook
Cottrell, Jas. W., Sergeant	Instructor Ordnance Motor Instruction School	Metuchen, N. J.
Cowan, Henry B., Sergeant, 1st Class	Co. D., First Telegraph Battalion, Signal Reserve Corps	France
Crampton, George S., Major	Director of Field Hospitals, 28th Div., A.E.F.	France
Cushman, A. S., Lieut. Col.	Ordnance Dept., U.S.N.A.	Frankford Arsenal
Detwiler, Jas. G., 1st Lieut.	Infantry, U.S.R.	Fort Logan H. Roots
Douredoure, Bernard L.	Signal Service Officers' Training Camp	Camp Meade

Name and rank	Branch of service	Location
Eckert, S. B., Lieut.	Commander 9th Aero Squadron	France
Edwards, John R., Rear Admiral	Brown University	Providence, R.I.
Elliot, A. H.	Engineers Reserve Corps	Philadelphia
Elliott, Henry M., 1st Lieut.	Ordnance Dept., U.S.R.	Western Cartridge Co.
Emerson, Geo. H., Colonel	In charge of Russian Railway Service Corps	Japan
Felton, Samuel M.	U. S. Director-General of Railways in connection with Expeditionary Force	Chicago
Ferguson, Walter B., Sergeant	21st Co., 154th Depot Brigade	Camp Meade
Fraser, Persifor, Ensign	U.S.N.R.F.	League Island
Gardner, H. A., Senior Lieut.	Naval Flying Corps	Washington
Gfrörer, A. H., 1st Lieut.	Ordnance Dept., U.S.R.	Washington
Gibbons, Joseph E., Private	Co. D., 103rd Engineers	France
Gilbreth, Frank B., Major	Engineers O. R. C.	Washington
Gillmor, R. E., Senior Lieut.	U. S. Navy	New York
Glendinning, Robt. E., Major	Aviation Section, Signal Corps	Overseas
Gomberg, M., Major	Ordnance Reserve Corps	Washington
Goodwin, Harold, Jr., Lieut.	Naval Reserve Force, office, Chief of Naval Operations	Washington
Gribbel, W. G., Major	Engineers	Camp Humphreys
Griest, Thos. S., 1st Lieut.	1st Telegraph Battalion, Signal Corps, U.S.A.	France
Hall, R. T., Rear Admiral	U. S. Navy, Inspector of Machinery	Cramps' Shipyard
Hammer, William J., Major	Inventions Section, War Plans Division, General Staff, War College	Washington
Hodges, Austin L., Capt.	Ordnance Dept., U.S.R., Experimental Officer on Artillery Ammunition	Frankford Arsenal
Howson, Richard, 2nd Lieut.	Field Artillery	Camp Zachary Taylor
Ives, H. E., Captain	Signal Corps, U.S.A.	Washington
Jackson, John Price, Major		France
Jones, Jonathan, Major	E.O.R.C., 23rd Engineers, A.E.F.	
Junkersfeld, P. Major	E. O. R. C.	Washington
Karrer, Enoch, Senior Master Engineer	488th Engineers	Washington
Kennedy, M. C., Colonel	Deputy Director General of Transportation	France
Kent, S. Leonard, Jr., 1st Lieut.	34th Engineers	France
Kingsbury, E. F., Captain	Air Service Dept. of Science and Research	Washington
LeBoutillier, H. W., Private	Unit No. 10, Pennsylvania Hospital	France
Lenher, Victor, Major	Chemical Warfare Service, N.A.	Madison, Wis.
Lichtenberg, Chester, 1st Lieut.	Engineer Reserve Corps, U.S.A.	Washington
Lippincott, Joseph Wharton, Yeoman, 1st class	U. S. Naval Reserves	Washington
Littleton, Wm. Richards	Assistant Paymaster, U. S. N.	Philadelphia
Longstreth, Chas., Lt. Commander	U.S.N.R.F.	New Castle, Del.
Lucke, Charles E., Lt. Commander	U.S. Navy Gas Engine School	New York City, New York
McCoy, John F.	Aviation Section, Signal Corps	Princeton
MacLean, Malcolm R., Major	154th Depot Brigade	Camp Meade

Name and rank	Branch of service	Location
McMeekin, C. W., Major	Army War College	Washington
Martin, Thos. S., 1st Lieut.	Erie Proving Ground	Pt. Clinton, O.
Masters, Frank M., Major	Ordnance Dept., U.S.R.	Washington
Maxfield, H. H., Lieut. Col.	19th Railway Engineers, U.S.N.A.	
Mershon, Ralph D., Major	E.O.R.C., U.S.A.	New York
Miller, Casper W., Major	Medical Corps. Division of Food and Nutrition	Washington
Miller, Fred. J., Major	Ordnance Reserve Corps	Centre Bridge, Penna.
Owens, R. B., Major	Chief Signal Officer, Base Section No. 3, A.E.F.	London
Parrish, T. R., Captain	Signal Corps	Washington
Pemberton, Henry R.	U. S. Naval Air Service	Key West, Fla.
Reber, Samuel, Colonel	Signal Corps, U.S.A.	New York
Richardson, Chas. E., 1st Lieut.	30th Engineers, U.S.R. (Gas and Flame)	France
Sessler, Grover C.	Assistant Civil Engineer, U. S. N. R. F.	Philadelphia
Spackman, Henry S., Lieut. Col.	Engineers, U. S. A.	France
Spruance, W. C., Jr., Lt. Col.	Ordnance Dept., National Army	Chevy Chase. Md.
Squier, Geo. O., Major General	Chief Signal Officer, U.S.A.	
Stanford, H. R., Captain	U. S. Navy	Boston
Synnestvedt, Arthur	Development Battalion	Camp Greenleaf
Thomas, Geo. C., Jr., Captain	Aero Service Squadron 96, Aviation Section, Signal Corps	France
Tilghman, B. C., Captain	A.D.C., 28th Div. Headquarters, U.S.A.	
Toulmin, H. A., Lieut. Col.	Assistant Chief of Staff, Air Service, A. E. F.	France
Ulmer, Carl D., Private	Chemical Warfare Service, A.E.F.	France
Vogleson, J. A., Major	Sanitray Corps	Camp Jas. E. Johnston
Wagner, Fred. H., Major	Ordnance Reserve Corps, Nitrate Division	Washington
Wagner, Fred. H., Jr., Sergeant	Co. E., 304th Engineers	Camp Meade
Wells, G. A., Captain	Ordnance Reserve Corps	Peoria, Ill.
Wetherill, W. C., Lieut.	U. S. N., R. F. C.	Philadelphia
Weyl, Charles N.,	U.S.N.R.F.	Philadelphia
Widdicombe, R. A., Major	C.Q.M., Chemical Plant No. 4	Saltville, Va.
Wood, Edw. R., Jr., Captain	18th Field Artillery, U.S.N.A.	France
Worrell, Howard Sellers, 2nd Lt.	Coast Artillery School	Fortress Monroe
Wyckoff, A. B., Lieut.	U. S. Navy	Ontario, Cal.
Yale, A. W. Major	Railway Artillery Reserves	France
Yorke, George M., Major	Signal Corps, U.S.R.	New York

MEMBERS DOING CIVILIAN WORK FOR THE UNITED STATES GOVERNMENT

Name	Appointment	Location
Akeley, Carl E.	Consulting Expert of Mechanical Devices, War Department	Washington
Anderson, Robt. J.	Aeronautical Mechanical Engineer on Metallography, Bureau of Aircraft Production	Pittsburgh, Pa.
Balls, William H.	Ships Draughtsman	Phila. Navy Yard
Bancroft, Joseph	Secretary, Local Board No. 1	Wilmington

Name	Appointment	Location
Baskerville, Charles	Working with Bureau of Mines, Ordnance Dept. (Gas Warfare, Shells, etc.)	New York
Bodine, Samuel T.	Vice-Chairman, District Exemption Board, No. 1, Eastern Judicial District of Penna.	Philadelphia
Burnham, George, Jr.	Dept. of Civilian Service and Relief, Public Safety Committee of Pennsylvania	Philadelphia
Charles, Bernard S.	Ordnance Inspector, U. S. Navy	Allentown, Pa.
Comey, Arthur M.	Chairman, Sub-Committee on Explosives, Chemistry Committee, National Research Council	Chester, Pa.
Condict, G. Herbert	Naval Consulting Board, Member Committee of Examiners	Plainfield, N. J.
Cooke, Morris L.	Chairman, Storage Committee of Munitions Board; Member on Staff, Emergency Fleet Corporation	Washington
Day, Charles	Member of Army War Council	Washington
Delano, Frederic A.	Member of Federal Reserve Board	Washington
Dunn, Gano	Chairman, Engineering Committee, National Research Council	New York
Garrison, Frank Lynwood	Chairman, U. S. Manganese Commission	Philadelphia
Gudeman, Edward	Emergency Fleet Corporation	Chicago
Henderson, George R.	State Advisory Engineer, Federal Fuel Administration for Pennsylvania	Philadelphia
Honaman, R. Karl	Associate Physicist, Bureau of Standards	Washington
Hornor H. A.	Electrical expert for Industrial Training, Emergency Fleet Corporation	Philadelphia
Hoskins, Wm.	Consulting Chemist, Advisory Committee, Bureau of Mines; Associate Member, Naval Consulting Board	Chicago
Humphreys, Rich'd L.	Director of Building Materials, Building Materials Div., War Industries Board	Washington
Hyde, Edward P.	National Research Council, Sub-Committee on Monocular vs. Binocular Field-Glasses (Chairman)	Cleveland
Insull, Samuel	Chairman, Illinois State Council of Defense	Chicago
Keller, Harry F.	Assistant Director of Allied Bodies, Department of Public Safety of Penna.	Philadelphia
Kennelly, A. E.	Conducting special course in radio-engineering for the U. S. Signal Corps, in conjunction with Prof. E. C. Chaffee	Harvard Univ.
Lloyd, E. W.	Asst. Secretary, Illinois State Council of Defense	Chicago
Merrick, J. Hartley	Director, Bureau of Camp Service, Penna. Div., American Red Cross	Philadelphia
Milne, David	Treasurer, American Red Cross, General Hospital No. 1	Philadelphia
Morris, Effingham B.	Treasurer, Committee of Public Safety, State of Pennsylvania	Philadelphia
Nichols, Carroll B.	Fuel Administration	Washington
Nichols, Wm. H.	Committee on Chemicals, Advisory Council of National Defense, Consulting Chemist, Bureau of Mines	New York
Osborne, L. A.	Member, National War Labor Board	Washington
Penrose, R. A. F., Jr.	Member of Geology Committee of the National Research Council	Philadelphia
Picolet, L. E.	Civilian Personnel, Trench Warfare Section, Ordnance Office	Washington

Name	Appointment	Location
Rapp, Isaiah M.	Special Investigator of Weights and Measures for the U .S. Food Administration	Norman, Oklahoma
Rautenstrauch, Walter	Committee of the National Research Council	New York
Richards, Joseph W.	Member of Naval Consulting Board	So. Bethlehem, Penna.
Rittmann, Walter F.	Consulting Chemical Engineer, U. S. Bureau of Mines	Pittsburgh
Robins, Thomas	Member and Secretary of the Naval Consulting Board	New York
Sauveur, Albert	Director of Research, Division of Metallurgy, Technical Air Service, A.E.F.	France
Sperry, Elmer A.	Member of Naval Consulting Board	Brooklyn, N.Y.
Sprague, Frank J.	Member of Naval Consulting Board, Chairman, Committee on Electricity and Shipbuilding	
Steinmetz, Joseph A.	Member National Research Council, Engineering Division	Washington
Stern, Max J.	Supervising Surgeon, Merchant Shipbuilding Corporation	Philadelphia
Swenson, Magnus	Federal Food Administrator for Wisconsin; Chairman, State Council for Defense	Madison, Wis.
Taggart, Walter T.	Consulting Chemist, Nitrate Division, Ordnance Department	Philadelphia
Talbot, Henry P.	Member of Advisory Board, Bureau of Mines (Gas Defense)	Cambridge, Mass.
Thomson, Elihu	National Research Council in coöperation with Council of National Defense	Swampscott, Mass.
Turnbull, William F.	Department of Labor	Washington
Wadleigh, Francis R.	Emergency Fleet Corporation	Philadelphia
Warwick, J. F.	Bethlehem Loading Co.	Mays Landing, N. J.
Wharton, Henry	Y. M. C. A.	France

Please send additional information and corrections to the Secretary.

REPORT OF THE PRESIDENT.

FOR THE FISCAL YEAR ENDING SEPTEMBER 30, 1918.

To the Members of the Franklin Institute:

Your Board of Managers has instructed me to report to you upon the work of the Institute for the year ending September 30, 1918. This writing is the report.

Your Board is able to report that in spite of the difficulties occasioned by the continued absence of the Secretary, the Science and Arts Assistant and four members of the Board of Managers, two of them Committee Chairmen, these absences being due to the war, all of the customary work of the Institute was carried on through the year.

The Managers hope that you will read the attached committee reports in full, and that this reading will bring to you the conviction that this work intrusted to them by you has been faithfully performed. It is by reading these committee reports that the members may obtain the greatest measure of knowledge of the affairs of the Institute.

The year's operating expenses of the Institute were considerably greater in some details than in previous years, but, as you may learn from the report of the Finance Committee, the financial condition of the Institute remains good.

There is nothing of moment that the Board can add to what has been said in previous reports in reference to the Building Fund, which now stands at $474,000, of which $245,000 is invested in the building site on Logan Square.

The opening of the new Parkway makes more evident the great value for the purposes of the Institute of the property we now own on Logan Square at and near the corner of Nineteenth and Race Streets. During the past year we have acquired one new building and lot on this site, so that the Institute now owns five buildings and lots fronting on Race Street and four fronting on Nineteenth Street in the rear of these five.

The Board is still confident that the knowledge of the work the Institute is doing—work of great value to the citizen and to the State—will ultimately attract the funds necessary to the provision of a building more conveniently located and more nearly adequate to the accomplishment of the Institute's purposes than is this old and beautiful structure.

The work of the year is set out in detail in the reports of the committees, attached hereto, and to be printed in full in the 1918 Year Book. I comment briefly upon these reports as follows:

The Library Committee, Doctor Leffman, chairman, reports 2388 additions to the Library. Other interesting information is contained in the report, including some reference to the difficulties of operation during the period of war.

The Committee on Museums, Mr. Outerbridge, chairman, reports a number of valuable additions to the group of models and historical apparatus.

The report of the Committee on Meetings, Doctor Alleman, chairman, is mainly a record of the stated meetings of the Institute held, the subjects discussed and the medals awarded. Members who read this report will have an appreciative knowledge of the importance of the lecture course.

The report of the Committee on Stocks and Finance, Mr. Forstall, chairman, contains a list of the funds held by the Institute and a statement of the receipts and expenditures of the year. I quote the last paragraph of this report in its entirety and express the hope that the members will read the report in full.

"The total increase since last year in the principal of all funds amounts to $14,040.91, of which the principal item is $12,778.97 for the Franklin Institute Building Fund. It is a gratifying fact that under war conditions we were able to close the year with a surplus in operating account of $539.38."

During the months of difficulty through which we recently have passed, reassuring, indeed, has been the knowledge that the securities owned by the Institute and in the custody of its Board of Trustees, Mr. Fraley, chairman, are in the main of the highest reliability and reasonably certain to retain their earning value. Your Board feels little anxiety about them, though there has been some shrinkage in their market value.

The report of the Committee on Sectional Arrangements, Doctor Keller, chairman, contains a statement of the meetings of the Sections, with their many important lectures and discussions. It is interesting to note that during the year joint meetings have been held with the American Society of Electrical Engineers, the Illuminating Engineering Society and the Physics Club.

The report of the Committee on Publications, Mr. Levy, chairman, in addition to the detail usual to the Annual Report of the Committee, calls attention to a reduction of 16 pages in the size of the Journal, made pursuant to the request of the government for a conservation of paper. A large increase in the cost per page of printing the Journal made this step important for reasons of economy in expenditure of the funds of the Institute, as well as in the stock of paper.

The report of the Committee on Instruction, Mr. Paul, chairman, contains a statement of the work undertaken at the government's request in the field of wireless transmission of intelligence, as well as the general detail of the usual work of the schools.

The report of the Committee on Science and the Arts, Doctor Creighton, chairman, is mainly a statement of the activities of the Committee during the year. It shows that the standards of the Committee were well maintained. Thirty-nine subjects were considered and twenty-one awards made.

The Committee on Exhibitions, Mr. Chambers, chairman, reports no activities during the year.

The Committee on Election and Resignation of Members, Mr. Gibbs, chairman, reports the election of—

Resident members	15	
Non-resident members	17	
Associate members	7	
Life members	5	
Second class stock members	1	
Total		45

The resignation of—

Resident members	16	
Non-resident members	13	
Associate members	1	
Total		30

The deaths of—

Resident members	5	
Non-resident members	7	
Life members	5	
Total		17

Total of resignations and deaths	47	
Dropped for non-payment of dues	10	
	57	
Losses in membership—all classes		12

In this connection your Board of last year reported to you as follows:

"Our membership grows slowly. We are not very good advertisers, and knowledge of the value of the Institute's work is not forced upon the community. We do not conduct campaigns for membership or for funds. Doubtless we will attract a larger membership when we are domiciled in a more prominent and popular location."

During the two years just past, many of the members of the Institute, those of them suitably aged and conditioned, have been absent from our councils in the active service of their country—a service of honor and of danger. And we have missed them. Those of us not so happily aged and conditioned have endeavored in our less heroic sphere to maintain the traditional work of the Institute, and, where opportunity has offered, to turn the energies of our organization to the furtherance of the great cause. The committee reports of the two years last past indicate the measure of success attained.

Fellow members of The Franklin Institute, important as is the service we and kindred institutions are created to render, there is another class of service not mentioned in our charter and, at the moment, more important to the world than the promotion of the mechanic arts, or aught else, and to the consideration of this and of our relation to it, with the approval of your Board of Managers, I devote a few sentences.

The great war, now happily ended, has had a profound influence on all the political and social relations of the civilized world. Even in our own country of free institutions and of equality of opportunity, the ferment of unrest—the thirst for change, sometimes, illogically, for the change's sake only—is present, as is also the impulse, often as illogical, to resist all or any change. With affairs political and affairs social we, as an institution, have nothing to do. In our democratic body, in the membership of The Franklin Institute, are men of many creeds and of many political convictions. As a body we have no political bias—we have no social formulæ. We rejoice that this is so. And we, members of The Franklin Institute, a democratic organization for the promotion of the scientific interests of the state and the citizen, may reasonably believe, and believing rejoice, that our institution, pursuing amid the political and social ferment of the time the even tenor of its way, one hundred years old, yet ever young, bearing a century of tradition, yet in step with the most modern thought, that this institution, composed of men of widely different social and political creeds, offers a compelling example in conservatism to the radical and in progress to the Bourbon. While we disclaim any function other than the promotion of the mechanic arts, we are a stabilizing influence on the political and social life of the community. This by-product of the Institute's efforts to be useful, though having nothing to do with its declared purposes, though not the result of any conscious effort, is none the less real, none the less valuable to the community. The realization of its existence should be an highly gratifying thought and a stimulating influence to each of us. This is the thought that came to me as I strove to apprehend the influence of the great world upheaval upon the Institute and of the reaction of the Institute upon it.

We enter the New Year—we face the problems of the new year confident that in the days to come as in the years past there will be opportunity for such useful work as the Institution is equipped to execute; and the members of your Board of Managers looking forward to this continuing opportunity are appreciative of the privilege and responsibility of the position of control to which you have chosen them.

Respectfully submitted,
The Board of Managers,
WALTON CLARK,
PHILADELPHIA, January 15, 1919. *President.*

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, January 8, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, January 8, 1919.

DR. H. JERMAIN CREIGHTON *in the Chair.*

The following report was presented for final action:

No. 2727: Stabilized-Platform Weighing Scale. Final action deferred.

The following report was presented for reconsideration:

No. 2708: Waterbury Hydraulic Speed Gear. Report referred back to Sub-Committee for a recommendation.

GEO. A. HOADLEY,
Acting Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section was held in the Hall of the Institute on Thursday evening, January 9, 1919, at 8 o'clock, with Mr. Walton Forstall in the chair. The minutes of the previous meeting were approved as read.

M. Luckiesh, Chairman of the Committee on Camouflage of the National Research Council, delivered an illustrated address on "The Principles of Camouflage for Land, Sea and Air." The underlying principles, the evolution of camouflage from a science to an art, and its practice were described. Factors governing the visibility of airplanes were discussed.

On motion of Lieut. W. C. Wetherill, a vote of thanks was extended to Mr. Luckiesh. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, January 8, 1919.)

RESIDENT.

MR. SAMUEL S. SADTLER, Consulting Chemist, 210 South Thirteenth Street, Philadelphia, Pennsylvania.

DR. THEODORE B. SCHNEIDEMAN, Oculist, 1831 Chestnut Street, Philadelphia, Pennsylvania.

CHANGES OF ADDRESS.

LIEUTENANT COMMANDER A. W. K. BILLINGS, Apartado 491, Barcelona, Spain.

MR. STERLING H. BUNNEL, 6 Hanover Street, New York City, New York.

PROFESSOR JOSEPH A. CORCORAN, 8 36th Avenue, Lachine, P. Q., Canada.

MAJOR GEORGE S. CRAMPTON, Director of Field Hospitals, Headquarters, 103 Sanitary Train, 28th Division, A. E. F., France.

MR. THOMAS DUNCAN, in care of Burlington Apartments, 9th Street and Burlington Avenue, Los Angeles, California.

LIEUTENANT R. E. GILLMOR, in care of Sperry Gyroscope Company, Manhattan Bridge Plaza, Brooklyn, New York.

MR. FRANCIS H. GILPIN, in care of Texas Company, Asphalt Department, 17 Battery Place, New York City, New York.

MR. F. G. GRIMSHAW, Assistant to General Manager, Pennsylvania Railroad Company, Eastern Lines, 724 Commercial Trust Building, 15th and Market Streets, Philadelphia, Pennsylvania.

MR. R. A. MARRIOTT, 213 Hickory Street, Anaconda, Montana.

MR. FREDERICK W. SALMON, 521 North 20th Street, Birmingham, Alabama.

MR. WILSON E. SYMONS, in care of Galena Signal Oil Company, 17 Battery Place, New York City, New York.

NECROLOGY.

William L. DuBois, a member of The Franklin Institute since 1866 and of its Board of Managers from 1880 to 1882, died at his home in Philadelphia on October 26, 1918, just at the close of his seventy-fourth year, he having been born in this City October 27, 1844. His active life was spent in the service of the Philadelphia Trust Company, of which he was President for many years before his retirement in 1910, remaining thereafter Chairman of its Board of Directors until his death.

Mr. DuBois was a son of William Ewing DuBois, long Assayer of the United States Mint, and the descendant of a noted Huguenot refugee, Louis DuBois, of New Paltz, New York. He is survived by his widow, Mary Cowell, and by his son, Captain Henry C. DuBois, who is stationed in Washington.

Isaac Norris, M.D., one of the very oldest members of The Franklin Institute, died October 22, 1918, after a short illness in Florence, Italy, where he had resided for some years past. Doctor Norris was in his eighty-fifth year, having been born in Philadelphia, June 12, 1834. He was a member of one of the historic families of Philadelphia, a granduncle and namesake of his having been one of the signers of the Declaration of Independence. He was graduated from the University of Pennsylvania in the class of 1852, and three years later obtained the degree of Doctor of Medicine. He served as Acting Assistant Surgeon of the Nicetown Hospital during the Civil War, and thereafter for two years as Physician of the Philadelphia Dispensary, being at the same time active as Professor of Chemistry of Central High School in Philadelphia.

Doctor Norris joined The Franklin Institute in 1866 and up to recent years, when his frequent journeys abroad eventuated in his taking up his residence in Florence, he took an active and prominent part in its affairs. He was a member of the Board of Managers from 1870 to 1878, then Secretary of the Institute from 1879 to 1881, and again a member of the Board from 1883 to 1918.

He evinced his interest in the general field of science by his active membership in various other societies. He was a member of the American Philosophical Society, Academy of Natural Sciences and the Historical Society of Pennsylvania, of various medical societies and a fellow of the Philadelphia College of Physicians and Surgeons and one of its Secretaries. He took a leading part in the movement for the establishment of a Free Public Library in Philadelphia, and the start of the present great institute was largely due to his efforts. His private library, now in the home of his son at Bryn Mawr, was collected by him in the course of his manifold activities and is a monument to his zeal as a booklover.

Doctor Norris married in 1862 Clara Lamb, and is survived by a son and daughter, Isaac and Clara Norris.

Mr. Walter V. Turner, Wilmerding, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

BONE, W. A.—Coal and Its Scientific Uses. 1918.

BREARLEY, A. W., and H.—Ingots and Ingot Moulds. 1918.

CROSBY, E. U., FISKE, H. A., and FOSTER, H. W.—Handbook of Fire Protection. 1919.

FERRY, E. S.—Handbook of Physics Measurements. 1918.

HALE, A. J.—Applications of Electrolysis in Chemical Industry. 1918.

HOFMAN, H. O.—Metallurgy of Lead. 1918.

JACOBY, H. S.—Structural Details, or, Elements of Design in Timber Framing. 1918.

TILDEN, SIR W. A.—Sir William Ramsay, Memorials of His Life and Work. 1918.

WALTON, ERICH.—Manual for the Essence Industry. 1916.

WATSON, E. R.—Colour in Relation to Chemical Constitution. 1918.

WEGMANN, EDWARD.—Conveyance and Distribution of Water for Water Supply. 1918.

PUBLICATIONS RECEIVED.

A Handbook of Physics Measurements, by Ervin S. Ferry, in collaboration with O. W. Silvey, G. W. Sherman, Jr., and D. C. Duncan. Vol. i, Fundamental Measurements, Properties of Matter and Optics. Vol ii, Vibratory Motion, Sound, Heat, Electricity and Magnetism. First edition, 2 vols., illustrations, 8vo. New York, John Wiley and Sons, Inc., 1918. Price, $4.00.

Topographic Stadia Surveying: A manual with reduction tables and a new type of reduction diagram, by C. E. Grunsky, Eng. D. 99 pages, illustrations, plates, 16mo. New York, D. Van Nostrand Company, 1917. Price, $2.00.

The Science of Fruit Growing Based on Nature's Laws, by Virgil Bogue. 83 pages, portrait, 24mo. Rochester, N. Y., Democrat and Chronicle Print, 1917. Price, $2.00.

U. S. Department of Agriculture: Bulletin 724. Professional paper. Drainage Methods and Foundations for Country Roads, by E. W. James, General Inspector; Vernon M. Peirce, Assistant Engineer; Charles H. Moorefield, Senior Highway Engineer. 86 pages, illustrations, plates, 8vo. Washington, Government Printing Office, 1918.

Canada Department of Mines: Summary report of the Mines Branch for the calendar year ending December 31, 1917. 153 pages, illustrations, map, 8vo. Ottawa, King's Printer, 1918. Price, 15 cents.

U. S. Bureau of Mines: California Mining Statutes, Annotated by J. W. Thompson, 312 pages, 8vo. Bulletin 157. Innovations in the Metallurgy of Lead, by Dorsey A. Lyon and Oliver C. Ralston. 176 pages, illustrations, 8vo. Bulletin 163. Methods of Shutting Off Water in Oil and Gas Wells, by F. B. Tongh. 122 pages, illustrations, plates, 8vo. Eighth Annual Report of the Director of the Bureau of Mines to the Secretary of the Interior for the Fiscal Year Ended June 30, 1918. 124 pages, 8vo. Technical paper 171. Method of Least Squares Applied to Estimating Errors in Coal Analysis, by J. D .Davis and J. G. Fairchild. 36 pages, illustrations, plate, 8vo. Technical paper 198. Sulphur Dioxide Method for Determining Copper Minerals in Partly Oxidized Ores, by Charles E. Van Barneveld and Edmund S. Leaver. 14 pages, illustrations, 8vo. Washington, Government Printing Office, 1918.

U. S. Tariff Commission: Dyes and Other Coal-Tar Chemicals. Report to Congress recommending amendments to title V of Act of September 8, 1916. 83 pages, 8vo. Washington, Government Printing Office, 1918.

Ontario Hydro-Electric Power Commission: Report on the Heating of Houses. Coal and Electricity Compared. 12 pages, 8vo. Report on the Rate of Coal Consumption in Various Electric Generating Stations and Industrial Establishments in Canada and the United States. 12 pages, diagrams, tables, 8vo. Toronto, Commission, 1918.

CURRENT TOPICS.

The Self-loading Military Rifle. E. C. Crossman. (*Scientific American,* vol. 119, No. 14, p. 272, October 5, 1918).—Every civilized nation has experimented with military rifles of the self-loading type. No rifle in pre-war days fulfilled all the necessary requirements in point of simplicity, endurance and reliability. Now, the demands on the rifle in the way of ease of cleaning and care, and immunity to abuse, mud and grit, are greater than in the days before the war, and the satisfactory rifle to fill the need seems farther away than ever. Rifles that do the work of breech manipulation are roughly divided into two classes—recoil-operated and gas-operated. Machine guns follow the same classification, and are about evenly divided in actual number now in operation. The Maxim, which is the standard German machine gun, is recoil-operated. The Benet-Mercier, the Lewis, and the Colt are gas-operated.

The sporting rifles sold to hunters are confined strictly to the recoil-operated type, represented by the Remington, the Winchester and the little known Sjogren of England. The designer of the recoil-operated, self-loading rifle—often miscalled "automatic"—is confronted with the difficult task of both locking his rifle firmly against the thrust of the cartridge, and yet utilizing that impulse to operate the mechanism. If it is permitted merely to oppose a heavy unlocked bolt and a powerful spring to the backward push of the cartridge, then the task is easy, and we get what is called the "blow-back" type of weapon, a type including the familiar and successful Winchester self-loading rifles and various automatic pistols. In that type there exists a necessarily delicate balance between backward thrust of the cartridge case, mass of the bolt and push of the retractor spring behind it.

If the bolt and spring offer inadequate resistance, then the speed of the recoiling parts will be too great and there will be an escape of powder gas at the breech, and probably rupturing the cartridge case because the back portion would be pushed out under the gas pressure, while the forward and thinner part remains tightly held in frictional contact with the chamber walls by the same powder pressure. If the bolt and spring offer too much resistance, then the breech mechanism will merely not function. Any overload or serious obstruction in the bore, tending to raise the chamber pressure, would destroy this balance, and so the refusal of the military boards to countenance this type of action. It, however, operates satisfactorily in sporting arms.

While necessitating a clumsy barrel cover, the Browning plan of recoil-operated rifle is thus far the most practical and one much copied in foreign rifles of the military automatic type. In the Browning plan, used in the big-game series of self-loaders, the recoil drives backward the breech-bolt and barrel firmly locked together, the barrel sliding in guides provided therefor. The backward motion compresses the retractor and mainsprings. At the end of the travel, which is about the length of a cartridge, a trip releases the lock between bolt and barrel, the heavy retractor spring drives the barrel forward to position again, ejecting the fired case, while the breech bolt is momentarily held back. A fresh cartridge rises into the path of the bolt, which then flies forward, carrying the cartridge into the chamber, and locks itself by the turning of the bolt head under locking shoulders, as with the Mauser hand-operated rifle. The Browning plan is used on the Danish Schoeboe rifle submitted in military form to our War Department in 1909. The same plan is embodied in the Swedish Kjellman rifle submitted in 1910.

A third application of the recoil principle is the forward-moving barrel idea seen in the Swartzlose automatic pistol sold in this country prior to the war. Here the " drag " against the light barrel is alleged to force the barrel forward to the limit of its travel. As a matter of fact the in-part backs away from the barrel, much as the Sjogren rifle backs away from the sliding locking bolt. This is proved by the fact that if the firing hand is placed against a wall and the trigger pulled, the arm will not function; the backward jump of the pistol has really more to do with the functioning of the arm than the actual forward motion of the barrel.

All devices depending on recoil, however, are more or less clumsy and complicated compared to the simple plan of taking a little gas from the barrel and using it to operate a miniature piston in a cylinder below the barrel. This is the operating principle of the Benet-Mercier and Lewis machine guns. The Colt uses gas, but lets it impinge on the lever hinged below the barrel. The small portion of gas used has no effect on the ballistics of the arm. Such gas operation permits the use of the simple and strong bolt of military type. It is quite safe in that the operation of the bolt cannot commence until the bullet passes the port near the muzzle and has only a short distance to travel before exit. The objections to gas operation are the slight tendency of the working parts to corrode from the gas and the slightly greater difficulty in keeping the bore clean, due to the creeping up of erosion from the unreachable gas-port in the barrel. Care can prevent this trouble.

(It is of interest to note that the retractor spring in a recoil-operated weapon has no appreciable effect in opposing the backward push of the cartridge; its sole function is to push a fresh cartridge into the barrel and to hold the breech bolt in place, and substantially the whole effect is due to inertia. This point was demonstrated with an early model 32-calibre Colt automatic pistol of the " blow-back " type. The retractor spring was removed and the pistol was fired, pointing downward to keep the bolt in contact with the cartridge. The arm functioned properly, except that the breech remained open.—ED.).

Lead Plating. ANON. (*Brass World*, vol. 14, No. 11, p. 321, November, 1918.)—According to a circular issued by the Bureau of Standards in collaboration with the Army Ordnance Department, lead plating is conducted similarly to any other plating operation, and can be readily installed and operated wherever there are plating facilities and an experienced plater. Wooden tanks, preferably lined with asphalt or bitumen, are suitable for the purpose; iron or lead linings should not be used. The solutions after mixing are not especially corrosive, and are not so poisonous as many other plating solutions in common use. Danger of lead poisoning may be avoided by the use of the customary precautions. Briefly, the operation of lead plating consists in hanging the properly cleansed articles in the plating solution upon the cathode rods and lead plates or sheets of suitable size upon the anode rods.

The only two solutions in extensive commercial use are the fluosilicate and fluoborate solutions. The former is made by dissolving lead carbonate in fluosilicic acid, which in turn is prepared by the action of hydrofluoric acid on silica. As the preparation of the fluosilicate solution is a rather complicated process, it is customary for the platers to purchase this solution from the refineries in which it is used on a large scale for the refining of lead. Observation has shown that most of the platers using fluosilicate solutions make further additions to the solutions as purchased, such as glue, molasses, oxalic acid, etc. The fluoborate solution is prepared by dissolving boric acid in hydrofluoric acid, and then adding the lead carbonate (in the form of a paste), and the requisite amount of glue, after which the solution is diluted to the desired volume or density. Dense, satisfactory deposits of lead can be produced in either the fluosilicate or fluoborate solution, but it is believed that for new installations the fluoborate solution will be most satisfactory. The fluoborate solution may be used to plate directly on steel, whereas in the fluosilicate solution the steel must first be copper-plated or receive other special treatment.

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THE COLOR OF WATER.*

BY

WILDER D. BANCROFT, Ph.D.,
Professor of Physical Chemistry, Cornell University.

The literature on the color of water is widely scattered; it appears not to have been read by anybody; and it is somewhat contradictory. It has, therefore, seemed desirable to collect the material in an accessible form as it constitutes an interesting chapter in the general subject of the colors of colloids.

Tyndall[1] has discussed the blue color of turbid media with special reference to the color of the sky and of the sea. In Newton's rings the color nearest to the central black spot is a faint blue—blue of the first order—corresponding to the film of air when thinnest. "If a solid or liquid, of the thickness requisite to produce this color were broken into bits and scattered in the air, Newton inferred that the tiny fragments would display the blue color. Tantamount to this, he considered, was the action of minute water-particles in the incipient stage of their condensation from aqueous vapor. Such particles suspended in our amtosphere ought, he supposed, to generate the serenest skies. Newton does not appear to have bestowed much thought upon this subject; for to produce the particular blue which he regarded as sky-blue, thin plates with parallel surfaces would be required. The notion that cloud-particles are hollow spheres, or vesicles, is prevalent on the Continent, but it never made any way among the scientific

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* Communicated by the Author.

[1] "Fragments of Science: The Sky; Voyage to Algeria; Niagara."

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the Journal.]

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men of England. De Saussure thought that he had actually seen the cloud-vesicles, and Faraday, as I learned from himself, believed that he had once confirmed the observation of the illustrious Alpine traveler. During my long acquaintance with the atmosphere of the Alps I have often sought for these aqueous bladders, but have never been able to find them. Clausius once published a profound essay on the colors of the sky. The assumption of small water drops, he proved, would lead to optical consequences entirely at variance with facts. For a time, therefore, he closed with the idea of vesicles, and endeavored to deduce from them the blue of the firmament and the morning and evening red.

" It is not, however, necessary to invoke the blue of the first order to explain the color of the sky; nor is it necessary to impose upon condensing vapor the difficult, if not impossible, task of forming bladders, when it passes into the liquid condition. Let us examine the subject. Eau-de-Cologne is prepared by dissolving aromatic gums or resins in alcohol. Dropped into water, the scented liquid immediately produces a white cloudiness, due to the precipitation of the substances previously held in solution. The solid particles are, however, comparatively gross; but, by diminishing the quantity of the dissolved gum, the precipitate may be made to consist of extremely minute particles. Brücke, for example, dissolved gum-mastic, in certain proportions, in alcohol, and carefully dropping his solution into a beaker of water, kept briskly stirred, he was able to reduce the precipitate to an extremely fine state of division. The particles of mastic can by no means be imagined as forming bladders. Still, against a dark ground—black velvet for example—the water that contains them shows a distinctly blue color. The bluish color of many liquids is produced in a similar manner. Thin milk is an example. Blue eyes are also said to be simply turbid media. The rocks over which glaciers pass are finely ground and pulverized by the ice, or the stony emery imbedded in it; and the river which issues from the snout of every glacier is laden with suspended matter. When such glacier water is placed in a tall glass jar, and the heavier particles are permitted to subside, the liquid column, when viewed against a dark background, has a decidedly bluish tinge. The exceptional blueness of the Lake of Geneva, which is fed with glacier water may be due, in part, to particles small enough to remain suspended long after their larger and heavier companions have sunk to the bottom of the lake.

" We need not, however, resort to water for the production of the color. We can liberate, in air, particles of a size capable of producing a blue as deep and pure as the azure of the firmament. In fact, artificial skies may be thus generated, which prove their brotherhood with the natural sky by exhibiting all its phenomena. There are certain chemical compounds—aggregates of molecules—the constituent atoms of which are readily shaken asunder by the impact of special waves of light. Probably, if not certainly, the atoms and the waves are so related to each other, as regards vibrating period, that the wave-motion can accumulate until it becomes disruptive. A great number of substances might be mentioned whose vapors, when mixed with air and subjected to the action of a solar or an electric beam, are thus decomposed, the products of decomposition hanging as liquid or solid particles in the beam which generates them. And here I must appeal to the inner vision already spoken of. Remembering the different sizes of the waves of light, it is not difficult to see that our minute particles are larger with respect to some waves than to others. In the case of water, for example, a pebble will intercept and reflect a larger fractional part of a ripple than of a larger wave. We have now to imagine light-undulations of different dimensions, but all exceedingly minute, passing through air laden with extremely small particles. It is plain that such particles, though scattering portions of all the waves, will exert their most conspicuous action upon the smallest ones; and that the color-sensation answering to the smallest waves—in other words, the color line—will be predominant in the scattered light. This harmonizes perfectly with what we observe in the firmament. The sky is blue, but the blue is not pure. On looking at the sky through a spectroscope, we observe all the colors of the spectrum; blue is merely the predominant color. By means of our artificial skies we can take, as it were, the firmament in our hands and examine it at our leisure. Like the natural sky, the artificial one shows all the colors of the spectrum, but blue in excess. Mixing very small quantities of vapor with air, and bringing the decomposing luminous beam into action, we produce particles too small to shed any sensible light, but which may, and doubtless do, exert an action on the ultra-violet waves of the spectrum. We can watch these particles, or rather the space they occupy, till they grow to a size able to yield the firmamental azure. As the particles grow larger under the continued action of the light, the azure becomes less deep; while later on a milkiness, such as we often observe in nature, takes the place of the purer blue. Finally the particles become large enough to reflect all the light-waves, and then the suspended 'actinic cloud' diffuses white light. . . .

"In the harbor of Gibraltar, on the morning of our departure, I resumed a series of observations on the color of the sea. On the way out a number of specimens had been collected, with a view of subsequent examinations. But the bottles were claret bottles, of doubtful purity. At Gibraltar, therefore, I purchased fifteen white glass bottles, with ground-glass stoppers, and at Cadiz, thanks to the friendly guidance of Mr. Cameron, I secured a dozen more. These seven and twenty bottles were filled with water, taken at different places between Oran and Spithead. And here let me express my warmest acknowledgments to Captain Henderson, the commander of *H.M.S. Urgent,* who aided me in my observations in every possible way. Indeed, my thanks are due to all the officers for their unfailing courtesy and help. The captain placed at my disposal his own coxswain, an intelligent fellow named Thorgood, who skilfully attached a cord to each bottle, weighted it with lead, cast it into the sea, and, after three successive rinsings, filled it under my own eyes. The contact of jugs, buckets, or other vessels was thus avoided; and even the necessity of pouring out the water, afterward, through the dirty London air.

"The mode of examination applied to these bottles has been already described. The liquid is illuminated by a powerfully condensed beam, its condition being revealed through the light scattered by its suspended particles. Care is taken to defend the eye from the access of all other light, and, thus defended, it becomes an organ of inconceivable delicacy. Were water of uniform density perfectly free from suspended matter, it would, in my opinion, scatter no light at all. The track of a luminous beam could not be seen in such water. But an amount of impurity so infinitesimal as to be scarcely expressible in numbers, and the individual particles of which are so small as wholly to elude the microscope, may, when examined by the method alluded to, produce not only sensible, but striking, effects upon the eye.

"The results of the examination of nineteen bottles filled at various places between Gibraltar and Spithead are here tabulated:

"Here we have three specimens of water, described as green, a clearer green and bright green, taken in Gibraltar Harbor, and off Cabreta Point. The home examination showed the first to be thick with suspended matter, the second less thick, and the third still less thick. Thus the green brightened as the suspended matter diminished in amount.

Table I.

No.	Location	Color of Sea	Appearance in Luminous Beam
1	Gibraltar Harbor	Green	Thick with fine particles.
2	Two miles from Gibraltar	Clearer green	Thick with very fine particles
3	Off Cabreta Point	Bright green	Still thick, but less so.
4	Off Cabreta Point	Black-indigo	Much less thick, very pure.
5	Off Tarifa	Undecided	Thicker than No. 4.
6	Beyond Tarifa	Cobalt-blue	Much purer than No. 5.
7	Twelve miles from Cadiz	Yellow-green	Very thick.
8	Cadiz Harbor	Yellow-green	Exceedingly thick.
9	Fourteen miles from Cadiz	Yellow-green	Thick, but less so.
10	Fourteen miles from Cadiz	Bright green	Much less thick.
11	Between Capes St. Mary and Vincent	Deep indigo	Very little matter, very pure.
12	Off the Burlings	Strong green	Thick, with fine matter.
13	Beyond the Burlings	Indigo	Very little matter, pure.
14	Off Cape Finisterre	Undecided	Less pure.
15	Bay of Biscay	Black-indigo	Very little matter, very pure.
16	Bay of Biscay	Indigo	Very fine matter. Iridescent.
17	Off Ushant	Dark green	A good deal of matter.
18	Off St. Catherine's	Yellow-green	Exceedingly thick.
19	Spithead	Green	Exceedingly thick.

"Previous to the fourth observation our excellent navigating lieutenant, Mr. Brown, steered along the coast, thus avoiding the adverse current which sets in, through the Strait, from the Atlantic to the Mediterranean. He was at length forced to cross the boundary of the Atlantic current, which was defined with extraordinary sharpness. On the one side of it the water was a vivid green, on the other a deep blue. Standing at the bow of the ship, a bottle could be filled with blue water, while at the same moment a bottle cast from the stern could be filled with green water. Two bottles were secured, one on each side of this remarkable boundary. In the distance the Atlantic had the hue called ultramarine; but looked fairly down upon, it was of almost inky blackness—black qualified by a trace of indigo.

" What change does the home examination here reveal? In passing the indigo, the water becomes suddenly augmented in purity, the suspended matter becoming suddenly less. Off Tarifa, the deep indigo disappears, and the sea is undecided in color. Accompanying this change, we have a rise in the quantity of suspended matter. Beyond Tarifa, we change to cobalt-blue, the suspended matter falling at the same time in quantity. This water is distinctly purer than the green. We approach Cadiz, and at twenty miles from the city get into yellow-green water; this the London examination shows to be thick with suspended matter. The same is true at Cadiz Harbor, and also of a point fourteen miles from Cadiz in the homeward direction. Here there is a sudden change from yellow-green to a bright emerald-green, and accompanying the change a sudden fall in the quantity of suspended matter. Between Cape St. Mary and Cape St. Vincent the water changes to the deepest indigo, a further diminution of the suspended matter being the concomitant phenomenon.

" We now reach the remarkable group of rocks called the Burlings, and find the water between the shore and the rocks a strong green; the home examination shows it to be thick with fine matter. Fifteen or twenty miles beyond the Burlings we come again into indigo water, from which the suspended matter has in great part disappeared. Off Cape Finisterre, about the place where the *Captain* went down, the water becomes green, and the home examination pronounces it to be thicker. Then we enter the Bay of Biscay, where the indigo resumes its power, and where the home examination shows the greatly augmented purity of the water. A second specimen of water, taken from the Bay of Biscay, held in suspension fine particles of a peculiar kind; the size of them was such as to render the water richly iridescent. It showed itself green, blue or salmon-colored, according to the direction of the line of vision. Finally, we come to our last two bottles, the one taken opposite St. Catherine's lighthouse, in the Isle of Wight, the other at Spithead. The sea at both these places was green, and both specimens, as might be expected, were pronounced by the home examination to be thick with suspended matter.

" Two distinct series of observations are here referred to—the one consisting of direct observations of the color of the sea, conducted during the voyage from Gibraltar to Portsmouth, the other carried out in the laboratory of the Royal Institution. And here it is to be noted that in the home examination I never knew what water was placed in my hands. The labels, with the names of the localities written upon them, had been tied up, all information regarding the source of the water being thus held back. The bottles were simply numbered, and not till all of them had been examined, and described, were the labels opened, and the locality and sea-color corresponding to the various specimens ascertained. The home observations, therefore, must have been perfectly unbiased, and they clearly establish the association of the green color with fine suspended matter, and of the ultramarine color, and more especially of the black-indigo hue of the Atlantic, with the comparative absence of such matter.

"So much for mere observation; but what is the cause of the dark hue of the deep ocean? A preliminary remark or two will clear our way toward an explanation. Color resides in white light, appearing when any constituent of the white light is withdrawn. The hue of a purple liquid, for example, is immediately accounted for by its action on a spectrum. It cuts out the yellow and green, and allows the red and blue to pass through. The blending of these two colors produces the purple. But while such a liquid attacks with special energy the yellow and green, it enfeebles the whole spectrum. By increasing the thickness of the stratum we may absorb the whole of the light. The color of a blue liquid is similarly accounted for. It first extinguishes the red; then, as the thickness augments, it attacks the orange, yellow, and green in succession; the blue alone finally remaining. But even it might be extinguished by a sufficient depth of the liquid.

"And now we are prepared for a brief, but tolerably complete, statement of that action of sea-water upon light to which it owes its darkness. The spectrum embraces three classes of rays—the thermal, the visual and the chemical. These divisions overlap each other; the thermal rays are in part visual, the visual rays in part chemical and vice-versa. The vast body of thermal rays lies beyond the red, being invisible. These rays are attacked with exceeding energy by water. They are absorbed close to the surface of the sea, and are the great agents in evaporation. At the same time the whole spectrum suffers enfeeblement; water attacks all its rays, but with different degrees of energy. Of the visual rays, the red are first extinguished. As the solar beam plunges deeper into the sea, orange follows red, yellow follows orange, green follows yellow and the various shades of blue, where the water is deep enough, follow green. Absolute extinction of the solar beam would be the consequence if the water were deep and uniform. If it contained no suspended matter, such water would be as black as ink. A reflected glimmer of ordinary light would reach us from its surface, as it would from the surface of actual ink; but no light, hence no color, would reach us from the body of the water. In very clear and deep sea-water this condition is approximately fulfilled, and hence the extraordinary darkness of such water. The indigo, already referred to, is, I believe, to be ascribed in part to the suspended matter, which is never absent, even in the purest natural water; and in part to the slight reflection of the light from the limiting surfaces of strata of different densities. A modification of light is thus thrown back to the eye, before the depth necessary to absolute extinction has been attained. An effect precisely similar occurs under the moraines of glaciers. The ice here is exceptionally compact, and, owing to the absence of the internal scattering common in bubbled ice, the light plunges into the mass, where it is extinguished, the perfectly clear ice presenting an appearance of pitchy blackness.[2]

"The green color of the sea has now to be accounted for; and here, again, let us fall back upon the sure basis of experiment. A strong white dinner-plate had a lead weight securely fastened to it. Fifty or sixty yards of strong hempen line were attached to the plate. My assistant, Thorgood, occupied a boat, fastened as usual to the davits of the *Urgent,* while I occupied a second boat nearer the stern of the ship. He cast the plate as a mariner heaves the lead, and by the time it reached me it had sunk a considerable depth in the water. In all cases the hue of this plate was green. Even when the sea was of the darkest indigo, the green was vivid and pronounced. I could notice the gradual deepening of the color as the plate sank, but at its greatest depth, even in indigo water, the color was still green.[3]

"Other observations confirmed this one. The *Urgent* is a screw steamer, and right over the blades of the screw was an orifice called the screw-well, through which one could look from the poop down upon the screw. The surface-glimmer, which so pesters the eye, was here in a great measure removed. Midway down, a plank crossed the screw-well from side to side; on this I placed myself and observed the action of the screw underneath. The eye was rendered sensitive by the moderation of the light; and, to remove still further all disturbing causes, Lieutenant Walton had a sail and tarpaulin thrown over the mouth of the well. Underneath this I perched myself on the plank and watched the screw. In an indigo sea the play of color was indescribably beautiful, and the contrast between the water, which had the screw blades, and that which had the bottom of the ocean, as a background, was extraordinary. The one was of the most brilliant green, and the other of the deepest ultramarine. The surface of the water above the screw-blade was always ruffled. Liquid lenses were thus formed, by which the light was withdrawn from some places and concentrated upon others, the water flashing with metallic lustre. The screw-blades in this case played the part of the dinner-plate in the former case, and there were other instances of a similar kind. The white bellies of porpoises showed the green hue, varying in intensity as the creatures swung to and fro between the surface and the deeper water. Foam, at a certain depth below the surface, was also green. In a rough sea the light which penetrated the summit of a wave sometimes reached the eye, a beautiful green cap being thus placed upon the wave, even in indigo water.

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[2] I learn from a correspondent that certain Welsh tarns, which are reputed bottomless, have this inky hue.

[3] In no case, of course, is the green pure, but a mixture of green and blue.

"But how is this color to be connected with the suspended particles? Take the dinner-plate which showed so brilliant a green when thrown into indigo water. Suppose it to diminish in size, until it reaches an almost microscopic magnitude. It would still behave substantially as the larger plate, sending to the eye its modicum of green light. If the plate, instead of being a large coherent mass, were ground to powder sufficiently fine, and in this condition diffused through the clear sea-water, it would also send green to the eye. In fact, the suspended particles which the home examination reveals act in all essential particulars like the plate, or like the screw-blades, or like the foam, or like the bellies of the porpoises. Thus I think the greenness of the sea is physically connected with the matter which it holds in suspension. . . .

"At some distance below the Whirlpool Rapids we have the celebrated whirlpool itself. Here the river makes a sudden bend to the northeast, forming nearly a right angle with its previous direction. The water strikes the concave bank with great force, and scoops it incessantly away. A vast basin has been thus formed, in which the sweep of the river prolongs itself in gyratory currents. Bodies and trees which have come over the falls are stated to circulate here for days without finding the outlet. From various points of the cliffs above this is curiously hidden. The rush of the river into the whirlpool is obvious enough; and though you can imagine the outlet must be visible if one existed, you cannot find it. Turning, however, round the bend of the precipice to the northeast, the outlet comes to view.

"The Niagara season was over; the chatter of sight-seers had ceased, and the scene presented itself as one of holy seclusion and beauty. I went down to the river's edge, where the weird loneliness seemed to increase. The basin is enclosed by high and almost precipitous banks—covered, at the time, with russet woods. A kind of mystery attaches itself to gyrating water, due perhaps to the fact that we are to some extent ignorant of the direction of its force. It is said that, at certain points of the whirlpool, pine-trees are sucked down, to be ejected mysteriously elsewhere. The water is of the brightest emerald-green. The gorge through which it escapes is narrow, and the motion of the river swift though silent. The surface is steeply inclined, but it is perfectly unbroken. There are no lateral waves, no ripples with their breaking bubbles to raise a murmur, while the depth is here too great to allow the inequality of the bed to ruffle the surface. Nothing can be more beautiful than this sloping liquid mirror formed by the Niagara in sliding from the whirlpool.

"The green color is, I think, correctly accounted for in the last Fragment. While crossing the Atlantic, in 1872–1873, I had frequent opportunities of testing the explanation there given. Looked properly down upon, there are portions of the ocean to which we should hardly ascribe a trace of blue; at the most, a mere hint of indigo reaches the eye. The water, indeed, is practically black, and this is an indication both of its depth and of its freedom from mechanically suspended matter. In small thicknesses water is sensibly transparent to all kinds of light; but, as the thickness increases the rays of low refrangibility are first absorbed, and after them the other rays. Where, therefore, the water is very deep and very pure, all the colors are absorbed, and such water ought to appear black, as no light is sent from its interior to the eye. The approximation of the Atlantic Ocean to this condition is an indication of its extreme purity.

"Throw a white pebble into such water; as it sinks it becomes greener and greener, and before it disappears, it reaches a vivid blue-green. Break such a pebble into fragments, each of these will behave like the unbroken mass; grind the pebble to powder, every particle will yield its modicum of green; and if the particles be so fine as to remain suspended in the water, the scattered light will be a uniform green. Hence the greenness of shoal water. You go to bed with the black Atlantic around you. You rise in the morning, find it a vivid green, and correctly infer that you are crossing the bank of Newfoundland. Such water is found charged with fine matter in a state of mechanical suspension. The light from the bottom may sometimes cross into play, but it is not necessary. A storm can render the water muddy, by rendering the particles too numerous and gross. Such a case occurred toward the close of my visit to Niagara. There had been rain and storm in the upper lake-regions, and the quantity of suspended matter brought down quite extinguished the fascinating green of the Horseshoe.

"Nothing can be more superb than the green of the Atlantic waves, when the circumstances are favorable to the exhibition of the color. As long as a wave remains unbroken no color appears; but when the foam just doubles over the crest, like an Alpine snow-cornice, under the cornice we often see a display of the most exquisite green. It is metallic in its brilliancy. But the foam is necessary to its production. The foam is first illuminated, and it scatters the light in all directions; the light which passes through the higher portion of the wave alone reaches the eye, and gives to that portion its matchless color. The folding of the wave, producing as it does a series of longitudinal protuberances and furrows which act like cylindrical lenses, introduces variation in the intensity of the light and materially enhances its beauty."

The question of the color of the Mediterranean and of other waters has been studied with a good deal of care by Aitken, whose work seems not to have received the attention which it deserves. Only a lengthy abstract of his paper is available and I quote from that.[4]

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[4] Aitken: Proc. Roy. Soc. Edin. 11, 472 (1882).

" The experiments were made with a special view of determining whether the selective reflection or the selective absorption theory gave the correct explanation of the blueness seen in water. According to the selective reflection theory the color is due to the light reflected by extremely small particles of matter suspended in the water, these particles being so small they can reflect only the short waves of light, or those which belong to the blue end of the spectrum. The other theory explains the color by supposing that water has a selective absorption for the rays of the red end of the spectrum—that water is in fact a blue transparent medium. Three different methods were adopted of testing the correctness of these rival theories, and all three proved the water of the Mediterranean to be blue by selective absorption, and show that light in passing through the water has the rays of the red end of the spectrum absorbed, and only those of the blue end transmitted. The first method tried was to find out what is the color of the illumination of submerged objects. This was done by taking a long metal tube, closed at the end with a glass plate, sinking it vertically in the water, and looking through it at white and different colored objects fixed near the end of the tube. When this was done, it was found that a white object appeared of a most beautiful deep and delicate blue at a depth of 6 m. If the selective reflection theory was true, submerged objects would be illuminated with a color complementary to that reflected by the fine particles, and would therefore appear orange or yellow, the exact color depending on the amount of green in the reflected blue. If the blue color of the sky, as generally supposed, is due to the reflection of the blue rays by small particles of matter suspended in the air, it obviously follows that light in passing through our atmosphere must become of a color complementary to the blue of the sky; and it is asked, may not this be one of the reasons why the sun near the horizon, and all artificial lights when seen at a great distance, appear more or less yellow?

" The second method of experimenting was by looking at a white surface through a considerable length of water contained in a blackened tube. The light transmitted was found to be blue, thus showing the water to have a selective absorption for the rays of the red end of the spectrum.

" The third method was by sinking white and different colored surfaces under water, and noting the change which took place in the colors. The colors selected were red, yellow, and purple. It was found that these colors when seen through the water changed in the same way as when seen through a blue transparent medium, such as a piece of glass. The white changed to blue. The red darkened very rapidly as it descended, a very small depth of water being sufficient to destroy all the color. At a depth of about 2 m. a very brilliant red was so darkened as to appear a dark brick red. Yellow changed to green by the water absorbing the red component of the yellow. An orange, as it sunk in the water, appeared to become more and more unripe, while a lemon became quite green. The purple surface quickly changed to a dark blue or violet by the selective absorption of the water. These changes, being all due to the cutting out of the red component of the colors, showed the water to have a selective absorption for the rays of the red end of the spectrum. If the water had been colored blue by selective reflection, then those test colors would all have appeared deficient in blue when sunk in the water, as the fine particles would reflect and scatter the blue rays. Experiments are described which show that when these colors are sunk in water colored blue by reflection from small particles, white changes to yellow, while yellow simply deepens in color, and purple grows redder.

"All these different methods of experimenting show this water to be a blue transparent medium, and that it acts in the same way as a solution of a blue salt or as a blue tinted glass. It is then shown that this selective absorption theory is not enough to account for the different color phenomena seen in water. A piece of blue glass or a blue solution have but little color when viewed from the side on which the light is falling, and it seems certain that light will penetrate pure water till it is all absorbed, and the water will look dark and colorless. Something more, and that of great importance, is obviously necessary to explain the different color phenomena seen in different waters, and in the same water at different times.

"If the water of the Mediterranean, when brilliantly colored, is examined by means of a concentrated beam of light, it is found to be full of fine solid particles in suspension. It is shown that it is to this dust of the sea—so to speak—that the Mediterranean owes its fine and varied coloring. The particles of this aquatic dust are large, and reflect not only the blue rays, like the supposed particles of the selective reflection theory, but they reflect rays of all colors, and the water, by its selective absorption, strikes down the red rays, and only the blue rays are reflected to the surface and to the eye. These solid particles determine the brilliancy, and the selective absorption of the water determines its color. The color and the amount of the suspended particles is then considered. It is shown that the color of the particles will have a marked influence in the appearance of the water. If the particles are yellow—sand particles, for instance—then a blue colored water will appear to be green, as the light reflected by the yellow particles is deficient in the rays of the violet end of the spectrum.

" In the Mediterranean the solid particles are whitish, and all the different color phenomena are easily explained by the different amounts of the reflecting particles at the different places. Where the color is deep blue there are few particles in the water, and but little light reflected; and, further, the light passes through a great amount of water, and undergoes a great amount of selective absorption before it is reflected to the surface and to the eye. But if there are many particles in the water much light is reflected, and the color is chalky blue-green, as the light does not pass through so great a depth of water, and is therefore not so deeply colored, nor has it so many of the green rays cut out as in the water where the particles are few and far separated.

" Color experiments on a small scale with a solution of Prussian blue and a fine white powder are described. If the solution of Prussian blue is placed in a vessel, the bottom and sides of which are dark and reflect no light, then the colored solution appears dark and colorless; but if a little of the white powder is added then the solution at once becomes brilliantly colored. By varying the amount of the powder in the water all the varied color effects of the Mediterranean can be reproduced, a little powder causing the solution to appear deep blue, and as more powder is added the brilliancy of the water increases, and its color changes from blue to chalky blue-green.

" The presence and the abundance of white reflecting particles is shown to be a characteristic of all finely colored waters, and the wave-washed shores of the Mediterranean are shown to be the factories in which are prepared its reflecting particles. The waves, as they beat on the shore, grind up the stones and rocks, and stir up a great amount of fine whitish solid matter, which gives the water along the shore a milky appearance.

"With the assistance of these whitish particles, we understand how it is that the brilliant blue-green of this sea depends so much on the continuance of sea-breezes. The longer the wave-mills have been at work the more fine powder has been produced along the shore, and more time given for the particles to be carried seaward, by the wave-mixed and wind-driven waters, and the blue-green which only extended in a narrow band along the shore, when the wind began to blow, is, after a few days of inshore wind, seen to extend far to sea. We also understand how it is that the color near shore is so brilliant and so much greener than outside. Near the shore there is a greater quantity of white solid matter in suspension; there is therefore more light reflected, and further, the light does not penetrate through so great a depth of water, and has not so much of the light of the red end of the spectrum cut out, and therefore looks greener than the water outside, the light from which has to penetrate a greater depth of the absorbing medium. The blueness and beauty of the Mediterranean would thus appear to be due to the blue transparency of its waters, coupled with the presence of white reflecting particles, and the variety in its coloring to the amount of the suspended particles at different places and at different times.

"From this we see the important influence which the geological formation of the shore has on the appearance of the water of a sea, as it determines the nature of the solid suspended particles. This is beautifully illustrated by the difference of coloring in the Mediterranean at Mentone and at Cannes. At Mentone, limestone is everywhere abundant along the shore, and this limestone, when ground up by the waves, produces an extremely fine and white powder, which mixed with the water, causes the sea at Mentone to be far more brilliantly colored than it is at Cannes, where there is but little limestone, and the shore is almost everywhere covered with sand, the débris of the surrounding rocks.

"In the experiments in the Mediterranean it was found that the solid particles were so abundant that they prevented the sun's rays penetrating in a direct line to any great depth. This was shown by the illumination of the white surface placed at some distance under the water, and seen through the empty tube, being the same, whether the surface was turned towards the sun or away from it. It was also shown by the fact that at a depth of 6 m. these solid particles were found to reflect about as much light as a white surface did. These solid particles act like a fog, and, while they stop the light penetrating in a direct line, yet allow it to penetrate much further by internal reflection. The sun's rays get entangled—so to speak—among the particles, and are reflected from particle to particle, becoming a deeper blue with each reflection, so that the particles become illuminated with blue light. From this it is obvious that the more transparent the water, and the greater the reflecting power of the particles, the more deeply colored will the water appear.

"The Lake of Como was the next water visited. A white surface seen through its waters showed it to be as deeply colored as the Mediterranean, yet the absence of white reflecting particles in its waters and its dark-colored bottom, cause it to appear comparatively dark and colorless. When a quantity of white reflecting particles are artificially mixed up with the water in this lake a fine blue-green cloud was formed, which remained visible for some time amidst the darker waters, and showed that all this lake required to make it brilliantly colored was the presence of white suspended particles in its waters. The waters of Como, in their passage from the lake to form the river Adda, change to a fine blue. This sudden alteration in the appearance of the water is shown to be probably due to the addition of fine reflecting particles to the water on entering the river. Lago Maggiore, compared with Como and the Mediterranean, looks greener than either, but reflects more light than Como.

"The Lake of Geneva, whose waters have been so highly praised by all writers, was next visited, and the explanation given of the coloring of the Mediterranean was found to apply here also. Near Bouveret, where the Rhone enters the lake, all the variety of color phenomena seen in the Mediterranean were repeated. The light colored muddy waters of the entering river, as they stretched far into the lake, represented the whitish waters near shore in the Mediterranean, and where this whitish stream mixed with the waters of the lake, the bright blue-green of the Mediterranean was reproduced, while further out the waters were deeper blue, rivalling in brilliancy those of the Mediterranean. The work done by the waves along the shores of the Mediterranean in manufacturing the light-reflecting particles, is for the Lake of Geneva, done by the grinding of the glacier mills and streams of the Rhone valley.

"The silt brought down by the Rhone was found to be composed of clean white particles, like fine white sand. Many of the particles are thin polished plates, and when examined by means of a concentrated beam of light, while in suspension in water, are seen to flash brilliantly in the strong light. This white solid matter brought down by the Rhone is constantly being deposited all over the bottom of the lake, and it is this whitish deposit which gives to the Lake of Geneva one of its peculiarities. The light reflected from the whitish bottom causes the water of the lake, all along the shore to appear of a peculiar light blue-green color, and enables us to judge of the depth of the lake at depths far beyond that to which we can see the bottom. We can only see a white surface of 15 cm. square to a depth of about 7 m., yet the light reflected from the bottom affects the appearance of the water at depths far beyond 7 m., showing that light penetrates by diffusion in these waters to far greater depths than it can directly. The brilliancy and beauty of the Lake of Geneva would thus appear to be due to the purity and transparency of its waters, coupled with the presence of an enormous amount of white reflecting surfaces, both in suspension in its water and deposited all over the bottom of the lake, the effect being intensified by the brilliancy of the reflecting particles.

"The color of the water in Lake Bourget was found to be similar to that in the Lake of Geneva, though at the time it was visited it was slightly more turbid. A white surface could not be seen to so great a depth as in Geneva, and the water, even in the middle of the lake, when examined by means of a concentrated beam of sunlight was found to be very full of suspended light-reflecting particles similar to those brought down by the Rhone. The examination of the water in these lakes was confined to the colored surface experiments, and to a spectroscopic examination of the internally reflected light. The results were all similar to those in the Mediterranean.

"In the beginning of autumn the sea off the west coast of Scotland, near the village of Ballantree, and also in Brodick Bay, was visited, and the water examined by means of submerged colored surfaces, and by means of the spectroscope. The water was here found to be much greener than any previously examined. A large quantity of this water was filtered, when it was found that most of the suspended particles were fine grains of sand. From this it is concluded that the greenness of our northern seas is in part due to the reflecting particles being yellow, and the reflected light, therefore, deficient in the more refrangible rays. These yellow sand particles not only explain part of the greenness of our northern seas, but they also explain their comparative darkness and deadness, the yellow sand particles reflecting so little light. The importance, however, of even these bad reflectors was very evident during the time the observations were being made. It was noticed that the water was much more brilliantly green during and immediately after an inshore wind, and when the filter showed the water to have a good deal of sand in suspension, than after a calm, when many of the particles had settled out. Some water collected about a mile seaward from Ballantrae was examined in a glass tube 7½ m. long, and was found to be of a blue-green color.

"The water of Loch Lomond was next examined, and found to be a perfect contrast to any previously described, being of a color nearly complementary to that of the Lake of Geneva. A white surface seen through its waters appeared yellow, and the submerged colored surafces showed its waters to have their greatest absorption for the rays of the violet end of the spectrum. Its waters reflect a slightly yellowish light, its spectrum being brightest in the yellow. This water is so deficient in reflecting particles that its brightness is never greater than what we call brown. If it was supplied with abundant reflecting particles Loch Lomond would be a yellow lake.

"Well waters were also examined for color by placing them in long tubes, and looking through the water at white and at colored surfaces. The tubes were in pieces, so that they could be fitted up in lengths of from 3 m. to 15 m., to suit the transparency of the water under examination. The tubes were fixed horizontally, and at a convenient height for looking through them, and the water to be tested was poured in till the tube was half full, so that by looking through the upper half of the tube the colored surface could be seen, and through the lower half the effect of the absorption of the water on the color, and on the brilliancy, of the transmitted light. The transmitted light was also examined by means of a spectroscope.

"The colors of the different waters were found to vary greatly. One sample was of a fine blue, others were green-blue, some green, whilst others were of colors between green and yellow, but all were of colors between blue and yellow. It was observed that the more transparent a water was, the nearer its color was to blue. Scarcely any light could be seen through 7 m. of any of the yellowish waters, whilst through this length all the bluish waters were quite transparent, and the spectroscope showed that some of the waters transmitted almost the entire light of the blue end of the spectrum, and only stopped the rays at the red end. When one of the bluish waters was examined in a tube 15 m., or nearly 50 feet long, it appeared of a fine blue-green as transparent as a piece of glass.

" Only a very little relation could be traced between the color of a water—when tested in long tubes—and its suitability for dietetic purposes.

" The *cause* of the color of water has been a frequent subject of speculation. Every substance which has been discovered in water has in turn been suggested as the cause of the color. When no useful purpose could be given for its presence, it was told off to do the ornamental, and make the water beautiful to the eye. All these speculations assume that the color is due to some impurity in the water. This, however, is obviously begging the question. It is first necessary to find out whether water has any color in itself, and what that color is, before we can say anything about the effect of impurities. As it would be impossible to prepare absolutely pure water, and as we might still be in doubt as to whether any color seen in purified water was due to the water or to the impurities, the following method of experimenting was adopted: Distilled water was prepared in two sets of apparatus; in one set the condensing tube, the collecting bottle, and the testing tube were all of glass; in the other set they were all made of brass. If the waters prepared in these two sets of apparatus have the same color, then the probability is that the color is due to the water, as the impurities will be different in the two samples, and they would probably give different colors. The result was, the color of the samples of water prepared in both sets of apparatus was the same—namely, blue. This conclusion was further confirmed by preparing another sample of the water, and condensing it this time in a platinum tube. The water so prepared was also found to be of a fine blue. All three samples were almost exactly the same color as Prussian blue. Standards of color were kept with which the different samples of water were compared, both for the color and for the amount of the color. As all the different samples of distilled water—after the apparatus was thoroughly purified—had the same color and amount of color, it seems almost certain that water is a blue transparent substance, and that the color in these experiments could not be due to impurities, which must have varied both in kind and in amount in the different samples of water. Further, as the amount of color in the Mediterranean water, and in the bluish well waters, was as near as could be judged the same as in pure waters, it does not seem necessary to call in the aid of impurities to account for the blue color seen in the lakes and seas, the color being principally due to the water itself, and the different substances in solution, instead of making the water blue, tend to change its proper color and make it green or yellow.

"The addition of impurities to water seems generally to change its color from blue to green, or to yellow, though there seems to be no reason why some impurity may not change it to a deeper blue. The selective-absorption of the water remains the same, while the impurities add their selective-absorption to that of the water, and while they change the color they also decrease its transparency. This explains why it is that the yellow well waters are so much less transparent than the blue. This must necessarily be so, as a very small depth of water destroys the rays which give yellow, and the transparency of yellow waters can only be the transparency of water for yellow light, which is very much less than for blue light. No attempt was made to find out what the different discoloring substances in water are. The task would evidently be an endless one, and of little value.

"The effect of the light reflected from the surface of the water is then referred to. It is shown that when the sky is covered with white clouds, the surface reflection is so strong as to mask the color of the water, and that when the sky is deep blue the sky-reflected light intensifies and deepens the apparent color of the water. The importance of the surface-reflected light is best seen when the sky is covered with clouds, and glowing with a color different from that of the water, as at sunset when the clouds are richly colored all over the sky and deeply down towards the horizon. The water will then, especially if calm, appear like a sea of molten metal glowing with sky-reflected light, so powerful and brilliant as entirely to overpower the light internally reflected by the water.

" Pure water having been shown to be perfectly transparent to the more refrangible rays, and as it absorbs the red rays, water, when looked at from the side on which the light is falling, must necessarily be dark, and cannot reflect any perceptible amount of blue light. We must, therefore, look to the solid particles in suspension in the water as the cause of the light reflected by water, and while the selective absorption of the water principally determines its color, its brilliancy is entirely determined by the suspended particles. It is shown why it is that though we have waters of many colors, yet we only observe the color when it is blue or green, and never when it is yellow. Amongst other reasons given is the much less brilliancy of yellow waters, this less brilliancy being due to the less transparency of the yellow waters compared to blue; only the reflecting particles near the surface are active in the yellow water, whereas the particles to a considerable depth in the blue can reflect their light to the surface. This is one reason why Loch Lomond is so much darker than the Lake of Geneva. Loch Lomond certainly has fewer and less powerful reflecting particles than the Lake of Geneva, but it is darker also, because only the particles to a much less depth can reflect their light to the surface.

" The waters of our northern seas, when provided with proper reflecting particles, such as air-bells and white particles, are shown to be much bluer than they generally appear. The brightness and blueness of the waters off the coast of Cornwall are shown to be due to the beaches along this coast being at many points covered with a whitish-colored sand, which gets mixed up with the water by the action of the waves. As the water of the sea is constantly circulating, it seems impossible that the same water can be one color at one place, and a different color at another, but we can easily see how the different colors and degrees of brilliancy can be produced by the color and the amount of suspended matter at the different places—where the water is mixed with whitish particles being bluish, and where mixed with yellow particles appearing greener—whilst its brilliancy is determined by the amount of suspended particles which may be present at the time in the water.

"In conclusion, a lake in the Cordilleras is referred to as combining all the conditions necessary for producing fine and brilliantly blue colored waters. The traveller in describing this lake says: 'Its waters were of the most extraordinarily brilliant blue I ever beheld.' From the description, this lake is in many respects like the Lake of Geneva. It is provided with an abundant supply of pure glacier water, free from discoloring impurities, but laden with abundance of white-reflecting particles, whose presence is evidenced by a 'white strip' around the lake."

In a letter to Professor Tait, dated Mentone, April 14, 1882, Aitken[5] says:

"Since coming here this time I have tested the sea with the polariscope and with the spectroscope. With an instrument by Hoffman, which gives colored bands with polarized light, I have been able to detect small, but decided indications of polarization in the light internally reflected by the water, the surface reflection being, of course, cut off when the observation was made. At present I think the polarization is due to regular reflection from the polished surfaces of some of the particles, which are seen to glance brightly in concentrated sunlight.

"I have also detected an absorption band in the green of the spectrum of the light internally reflected by the Mediterranean water. This band is much more distinct in water where there are but few reflecting particles, and the light undergoes a great amount of selective absorption. At about a mile from shore, where I could see a white surface 6 inches square at a depth of 16 metres, the absorption band was quite distinct, but became less and less as I approached the shore, where there was more matter in suspension and the water less transparent, but the spectrum more brilliant. I cannot say whether this band belongs to water or to salt, or to what it is due, never having noticed it before; but I never examined water so transparent, and where the light had undergone so much absorption."

Subsequently to Aitken, but apparently independently, Spring[6] made a thorough and interesting study of the color of water. "Water in large masses always appears colored to us; but the color is not always the same and the tints are rich and vary enormously. The Mediterranean is the most beautiful indigo;

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[5] Aitken: Proc. Roy. Soc. Edin. **11**, 472 (1882).

[6] Bull. Acad. roy. belg., (3) **5**, 55 (1883).

the Atlantic is sky-blue; the Lake of Geneva is famous for the beauty of transparency of its azure waters; the Lake of Constance, the Rhine which flows from it, the Lake of Zürich and the Lake of Lucerne are just as transparent, but the waters are more green than blue. The little Kloenthaler Sea near Glaris can scarcely be distinguished from the surrounding fields, the water is so near the color of the grass on the banks. Among the more deeply colored waters I will mention only the Lake of Staffel near Murnau at the foot of the Bavarian Alps. On the day that I saw it, the water seemed absolutely black, although perfectly clear when seen in thin layers."

(To be concluded.)

A New Alloy. ANON. (*American Machinist,* vol. l, No. 8, February 20, 1919, p. 374.)—Because of the high temperature required for suitably hardening tools of tungsten high-speed steel Sheffield toolmakers have sought a substitute metal.

A new alloy produced by adding cobalt to chromium-carbon steel is reported to be best hardened by a temperature of 1200° C. For most purposes the hardening required is obtained when the tool is cooled naturally in draft-free air. In a comparative test saws of "cobalt-crom," as the new steel is called, continued cutting for four days, it is stated without regrinding, while saws of tungsten high-speed steel were dulled in two days and those of carbon steel in half a day.

Bibliography of Screw Threads. H. E. HAFERKORN. (*Professional Memoirs Engineer School,* Washington Barracks, vol. x, No. 54, November-December, 1918, Supplement No. 2.)—The aim of this bibliography is to furnish accounts, as complete as possible, of the various domestic and foreign forms and systems of screw threads together with professional reports relating to actual experience and study. In all, 379 titles are recorded. The value of a list which brings within reach many scattered monographs on this important subject is obvious. An index to authors, titles, subjects and topics is included.

Relation of Dehydration to Agriculture. G. C. PRESCOTT. (*U. S. Dept. of Agriculture, Circular 126,* January 25, 1919.)—Drying has been known for hundreds of years and is probably the oldest method of food preservation which the human race has employed. In this country it was used in the early colonial days for both animal and vegetable foods. Massachusetts colonists dried corn after it had been cooked, the product being known as samp. Fruits, and especially the apple, were also dried in considerable quantities. Along the coast, the drying of fish became an important industry. In other parts of the country, other vegetables and fruits and meat products were dried. Peas and sweet corn may be mentioned as examples of the former, while along the Pacific coast, the long sunny period lends itself particularly to the drying of prunes, raisins and other fruits. In the arid regions of the interior, the Indians, and later the early settlers, dried their beef or buffalo meat by cutting into thin strips and hanging up for sun and wind to remove the excess moisture and sear over the outside with a protective coating which would prevent infection and spoilage. This was known as jerked beef.

The advantages of dehydration are almost too obvious to require extended statement. Most evident of all is the loss in weight. Vegetables in common use contain from 60 to 95 per cent. of water. The dehydrated product should contain from 5 to 10 per cent. of water. There is therefore a very large reduction in weight and consequent saving in transportation charges, which are in general based upon weight. Similarly there is a loss in bulk amounting from 50 to 80 per cent. of the bulk of the raw material. From the standpoint of agriculture, the greatest advantage of dehydration is in the stabilization of crops and the conservation of materials. With dehydration, the excess of the years of great yield can be stored up and made available in the following year when prices are higher and the crop much smaller. Another great advantage is in the conservation of food materials. It is estimated that over 50 per cent. of the fruits and vegetables grown in this country never reach the consumer as a result of poor transportation facilities, irregularities in marketing or other causes. A third factor of importance in relation of dehydration to agriculture lies in the better diversity of crops that can be secured, and as a result of this the greater variety available to poor and rich alike throughout the year.

VEHICULAR TUNNELS UNDER THE HUDSON RIVER.*

BY

MARTIN SCHREIBER, M.Am.Soc.C.E.,
Chief Engineer, Public Service Railway Co., Newark, New Jersey.

THE population of metropolitan New York, say within a radius of ten miles, is about 7,000,000 people. On Long Island, and in Brooklyn and Queens, which are separated from Manhattan by the East River, and in Richmond, there are 2,500,000 people. On the Island of Manhattan and the Bronx and to the north within this radius, the population is 3,000,000 people. On the New Jersey side of the Hudson River there are about 1,500,000 people.

The transportation needs for such a community present a tremendous problem. The problem is complicated by the fact that metropolitan New York is not only the great gateway of the country, but one of the great ports of the world. Here we have railroads, aggregating approximately 29,000 miles, terminating on the Jersey side of the Hudson. On the Manhattan side of the Hudson there are termini representing about 11,000 miles, making a complete termini in the metropolitan area of approximately 40,000 miles of railroad. Moreover, there are seventy-seven foreign steamship lines operating from the port to all parts of the globe. There are more manufacturers in this district than the combined number in Chicago, Philadelphia and St. Louis. In this metropolitan area, Long Island and Manhattan districts are tied together over the East River by a number of bridges. These are the Brooklyn, Manhattan, Williamsburg and Queensboro bridges, which are among the largest structures of their kind in the world. Crossing the East River on these bridges are tweny-six railroad tracks and four highway roads for vehicles, with fourteen additional tracks in tunnels.

In striking contrast to the facilities over the East River are those across the Hudson River connecting the New Jersey district with the remainder of the metropolitan area. Here there are only six railroad tracks operating through tunnels under the Hudson River, two by the Pennsylvania Railroad and four by the Hudson and Manhattan Railroad. There are no highways at all. So the remaining business, either vehicular or passenger, must be transported by means of ferryboats.

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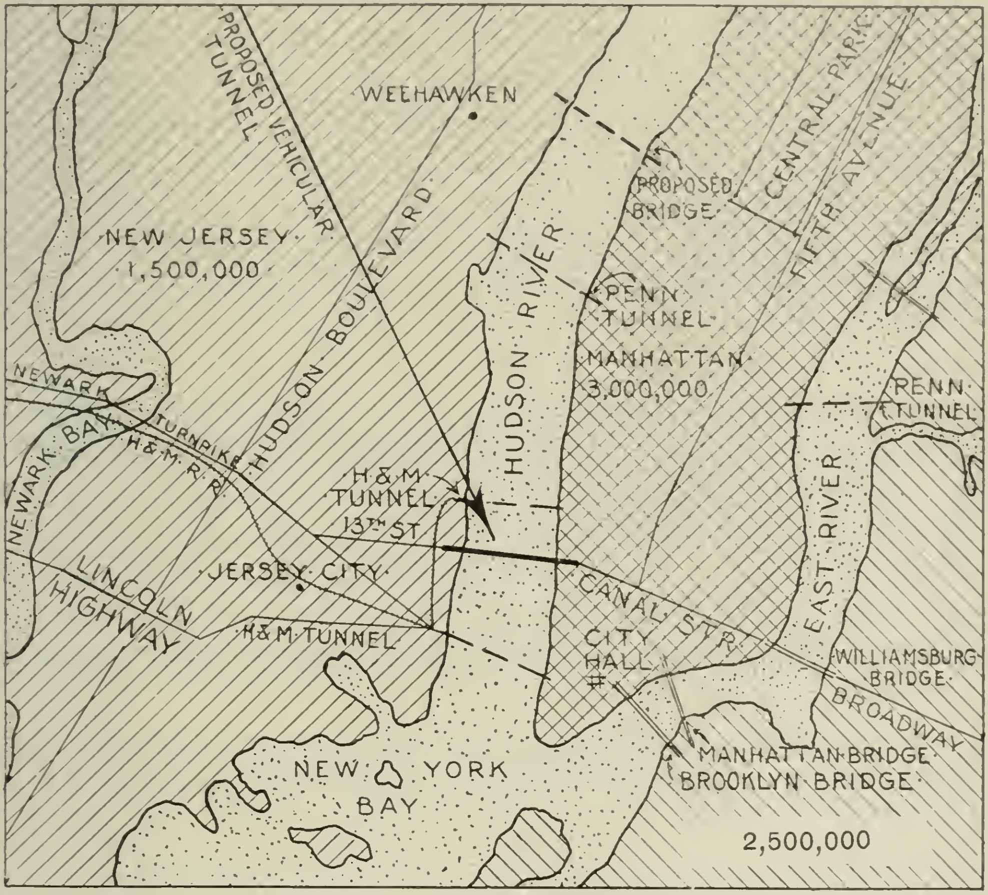
* Presented at the Stated Meeting held Wednesday, December 18, 1918.

Even to the most casual observer it must be evident that the New Jersey side of the metropolitan district is at a great disadvantage when compared to the remainder of the area. Taking the steam railroads, for example, with seventy-three per cent. of all the mileage entering the Port of New York, or termini representing about 29,000 miles, stopping on the Jersey side of the Hudson with the major part of their business to be done on the opposite side of the river, certainly creates a condition which is not economically sound.

In the early days it was not such a serious problem to ferry the cars, vehicles and people across the river. But as the district developed, more ferries, more tugs, more car floats and more lighters had to be brought into play, and now with the increased maritime business the river is congested with watercraft. Present facilities are entirely inadequate to meet the growing demands of the community, even under favorable conditions. When the river is blanketed with fog or filled with ice, not an uncommon occurrence, the whole transportation scheme is thrown out of gear. The stranger has this strongly impressed upon him if he happens to drive over the Lincoln Highway to Jersey City, for before he can get on a Cortlandt Street or Desbrosses Street ferryboat, we will say, it will be necessary for him to run a blockade of trucks, automobiles and other vehicles that clog Montgomery Street, Jersey City, for several blocks.

A large portion of the food supply for 7,000,000 persons is brought to the piers on the west side of the Hudson by the railroads. Owing to the congested and generally inadequate terminal facilities there is wastage of perishable food products before distribution can be made.

The bridging of the Hudson River at New York is a question that has been before the people of the States of New York and New Jersey for at least thirty years. No doubt a bridge would have been constructed long ago if it had been possible to finance the proposition. Unfortunately, the first outlay for such a structure would be very great, as it would be necessary to build a bridge large enough to anticipate future as well as present needs. It would be very uneconomical to build two or more bridges, when a little more money spent for a given bridge would double its carrying capacity. This is especially true of such a bridge as has been proposed for the Hudson River, with a span of almost 3000 feet, which must be of abnormal width and strength to even carry its own weight. An idea of the magnitude of a Hudson River bridge may be obtained when it is realized that the bridge proposed by Boller, Hodge & Baird, consulting engineers for the New York State Bridge and Tunnel Commission, to be built at Fifty-seventh Street, would have had a single span of almost twice the length of the Manhattan or Brooklyn Bridge spans. The plans called for a span longer than that of any bridge in the world. The proposed bridge was to be 170 feet clear above high water and its towers to support the suspension cables were to reach 600 feet above the water. The width of the bridge was fixed at 204 feet. Its proposed capacity was eight tracks for rapid transit



Map showing location of proposed vehicular tunnel.

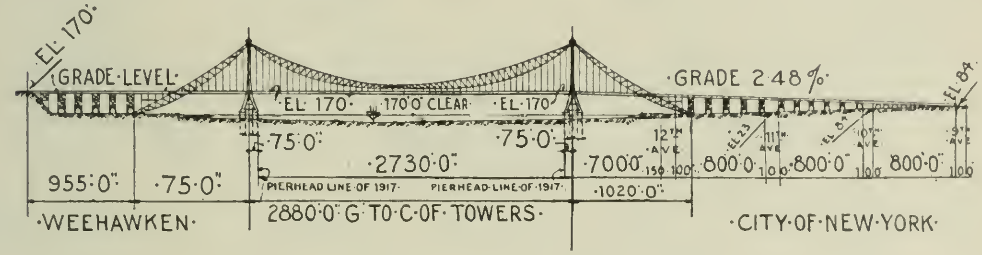
trains, two driveways (each thirty-six feet in width) and two eight-foot sidewalks. In 1913 the cost of the Fifty-seventh Street Bridge was estimated at $42,000,000. No doubt it would now cost nearly double that amount and it would take from six to ten years to construct it.

Any one who has given thought to the traffic situation in the metropolitan area would say that such a bridge across the Hudson would be a tremendous boon to both New York and New Jersey, and would go a long way toward providing and equalizing transportation facilities. On the other hand, as pointed out, the financing of such a project has its drawbacks. Naturally enough, with the development and possibilities of freight and passenger automobiles, many have turned their thoughts toward other means of crossing the Hudson, and tunnels naturally suggested themselves. In the first place, a tunnel could be built for a relatively nominal sum, say ten to fifteen million dollars, and the time of construction would not be more than two years. Again, it would not be a case of "putting all your eggs in the same basket," as a tunnel could be built in a comparatively short time, and, if it was successful, others could follow at any desired location. Further, it would seem that if we are not able to get a great bridge, with all the splendid benefits that would accrue, we should not deny ourselves any measure of improvement that may be within our reach.

In the last few years three separate reports have been made on the feasibility of vehicular tunnels under the Hudson River at New York:

(1) Report of Messrs. Jacobs & Davies, Consulting Engineers for the New Jersey Interstate Bridge and Tunnel Commission.
(2) Report of Special Committee on Vehicular Tunnel Project, to Public Service Corporation of New Jersey.
(3) Report of General G. W. Goethals for the Interstate Bridge and Tunnel Commissions of New York and of New Jersey.

All three reports agreed on the one location, which was first proposed by Messrs. Jacobs & Davies, and extends from Twelfth Street, Jersey City, to Canal Street, New York. The termini of the tunnel at both ends are located in the centre of the trucking and freight districts. The terminus on the Jersey side is not only in the midst of a busy industrial centre, but is also adjacent to the great freight yards of the Erie, Pennsylvania and Lackawanna Railroads and close to the Christopher, Barclay, Desbrosses, Chambers and Cortlandt Street Ferries. The tunnel would be in direct line with the Newark and Jersey City Turnpike, the Belleville Turnpike and Lincoln Highway on the Jersey side of the Hudson; while on the New York side, it would be in direct communication with the Manhattan and Williamsburg bridges to Brooklyn and Long Island. So, it is seen that this location is particularly favorable with relation to main traffic arteries. Also, not far from the vicinity of the terminus on the Jersey side is one of the largest trans-Atlantic terminals in existence. On the New York side are the piers of numerous steamship companies, such as the New England Navigation Company operating to Fall River and Portland; the Central Hudson Steamboat Company with its Hudson River boats; the Royal Mail Steam Packet Line to Bermuda and the West Indies, and the Southern Steamship Company to the Gulf Ports.

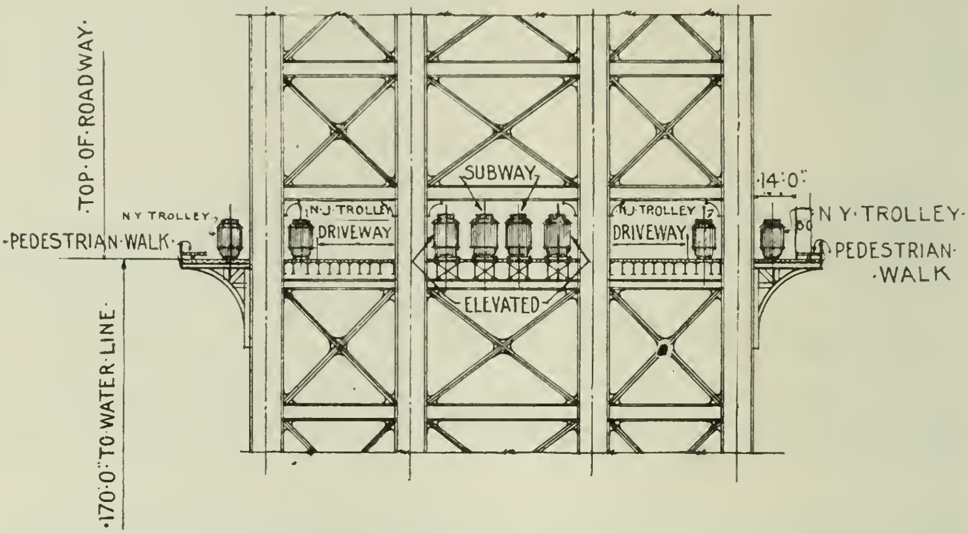


Proposed Hudson River bridge, near 57th Street. 2880′ 0″, center span; 4920′ 0″, between anchorages; 8330′ 0″, entire length from 9th Avenue to top of Palisades; maximum grade, 2.48 per cent. (*Boller, Hodge and Baird.*)

It was estimated by Mr. Percy Ingalls, of the Special Committee of Public Service Corporation of New Jersey, referred to heretofore, that by 1920 at least 4,000,000 vehicles a year will be crossing the five adjacent ferries and that at least 2,000,000 would use a tunnel if one were constructed. In this connection it is interesting to note that the Blackwall and Rotherhithe Tunnels under the Thames River, England, handle only about 1,000,000 vehicles each per annum.

When the unusually favorable location of the tunnel proposed is considered, it does not appear that there would be much of a risk involved in building at least a single tunnel between Twelfth Street, Jersey City, and Canal Street, New York. In addition to lending itself to vehicular business, such a tunnel could be adapted to almost any scheme for the development of the transportation systems of the Port of New York.

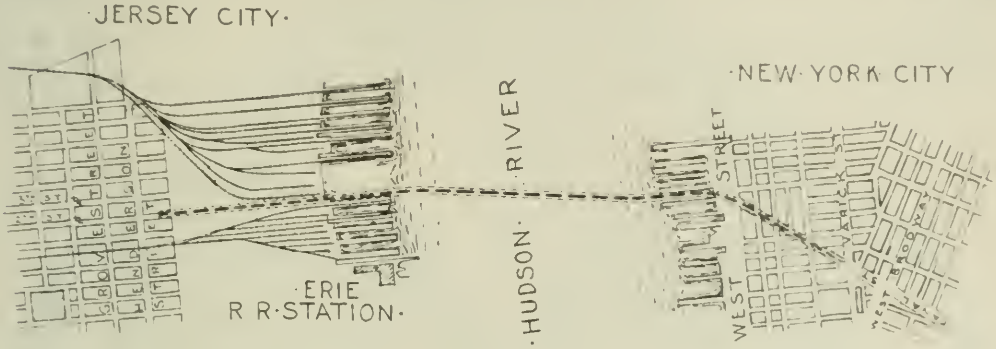
So far as the methods of construction of the proposed vehicular tunnel are concerned, there are differences of opinion as to certain engineering features. The first and third reports, already referred to, recommend that the tunnel be driven by the well-known shield and compressed air method. This was the method used in constructing the present tunnels under the Hudson and East Rivers, and was also used for the existing tunnels under the Thames River, England. With this plan a shield chamber is sunk at one or both ends of the tunnel and the shield installed.



Sectional view of tower for proposed Hudson River bridge, near 57th Street.
(*Boller, Hodge and Baird.*)

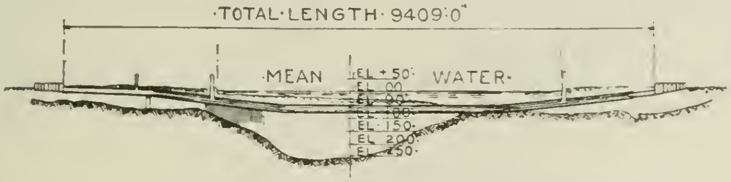
For example, the shield in the case of the Pennsylvania Railroad tunnels across the Hudson at Thirty-fourth Street, as designed by Mr. Charles M. Jacobs, the consulting engineer, was about eighteen feet long and twenty-three feet in diameter, and made of three-quarter-inch plates which also formed the cutting edge. The shield was forced forward by twenty-four hydraulic jacks that exerted a pressure of 3400 tons. As the shield was moved ahead by displacement of the silt or mucking through doors in the bulkhead, it was followed up by the installation of a cast-iron sectional lining that was bolted together and caulked watertight.

The first reports, recommending the usual shield-driven tunnel, included the customary iron lining. The third report, also recommending a shield-driven tunnel, included a special concrete block lining. The shield-driven tunnel has the advantage of being not only well tried but may be carried out without disturbing the surface of the land or water along the route of the tunnel, except, say, at the approaches. Although the first and third reports recommended the shield-driven tunnel, they do not recommend the same cross-section. Jacobs & Davies' report proposes two single tubes approximately twenty-seven feet in diameter with seventeen foot roadways and a walk on each side. This arrangement would allow two lines of vehicles, one slow moving and one fast moving, in each tube; or four lines of vehicles in both tunnels. It also has an advantage in natural ventilation, as vehicles moving in the same direction have a tendency to exhaust the foul air that is replaced with a certain quantity of fresh air from the mouth of the tunnel.



PLAN.

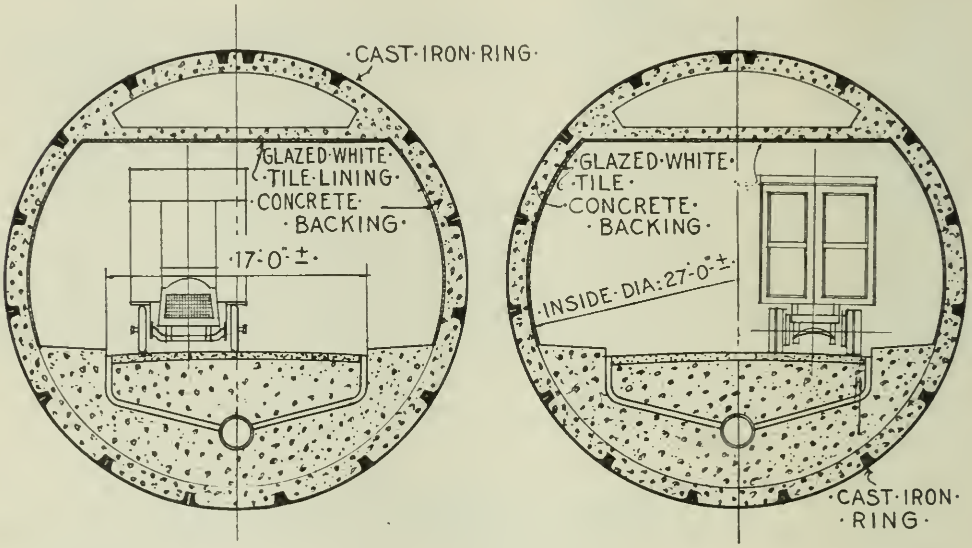
Proposed vehicular tunnel between 12th Street, Jersey City, and Canal Street, New York City. Total length, 9409′ 0″; length between bulkhead lines 5495′; length between pierhead lines 3724′; maximum grade New Jersey approach 4.55 per cent.; maximum grade New York approach 3.85 per cent. (*Burr, Modjeski and Moran.*)



Profile. Maximum depth at low water 55′ 0″.

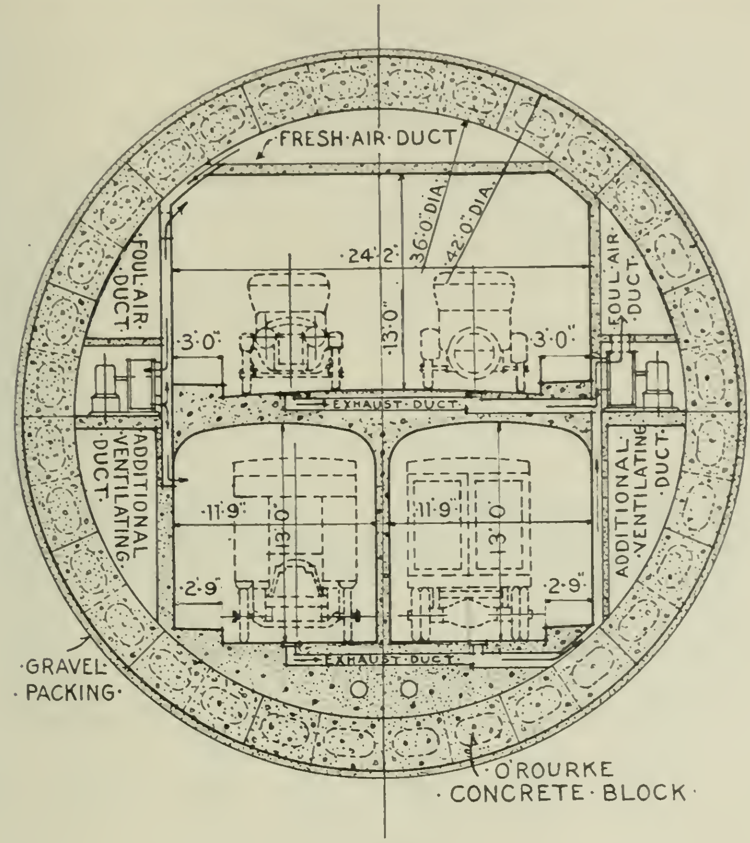
Gen. Geo. W. Goethals advocates a shield-driven single tube, thirty-six feet in diameter, with two eighteen-foot roadways, one superimposed above the other and a concrete floor between them. Such a cross-section would also allow four lines of vehicles, two of the faster-moving type (such as pleasure automobiles) on the upper floor, and two of the slower-moving vehicles (such as automobile trucks) on the lower floor.

The second report, as proposed by Messrs. Wm. H. Burr, Ralph Modjeski and Daniel E. Moran, the board of engineers for Public Service Corporation of New Jersey, differed from the other two both in character of the cross-section of tunnel and in method of construction. This report proposes a single tube, having a seventeen-foot roadway, with an elliptical cross-section. The tunnel was to be of reinforced concrete and have a minimum thickness of four feet. It was to be an arch section and so designed as to sustain to the best advantage the varying pressures of water at different depths, so that the section really constituted what is known as an hydrostatic arch. The tube was intended to accommodate only two lines of vehicles running in opposite directions. Its operation was to be similar to the Blackwall and Rotherhithe Tunnels under the Thames River. The maximum capacity of this tunnel was figured at 6,000,000 vehicles per year, two or three times as many as it was thought it would be called upon to accommodate for a long time. The entire length, from portal to portal, was 9409 feet, with 5495 feet between bulkhead lines. It was proposed to build the river section 2680 feet long, by excavating a trench so that the bottom of the same would be eighty feet below mean low water. The width of the trench at the bottom was to be forty feet and it was to be sloped off at an angle to the horizon of one to three. Piles were then to be driven in the trench on five-foot and eight-foot centres, and cut off at about seventy-eight feet below low water.



Cross section of proposed vehicular tunnels under Hudson River. (*Jacobs and Davies.*)

These piles were to form a foundation for the reinforced concrete tunnel. Each section of the tunnel, which was to be eighty feet long, was to be completed on launchways at convenient locations. After closing these sections with timber bulkheads and towing them to the tunnel site they are to be sunk in place. After the sections were joined together by specially designed joints the bulkheads were to be removed. This method of construction is not altogether new, as somewhat similar methods were used in connection with the Detroit River Tunnel and the tunnel across the Harlem River, New York.

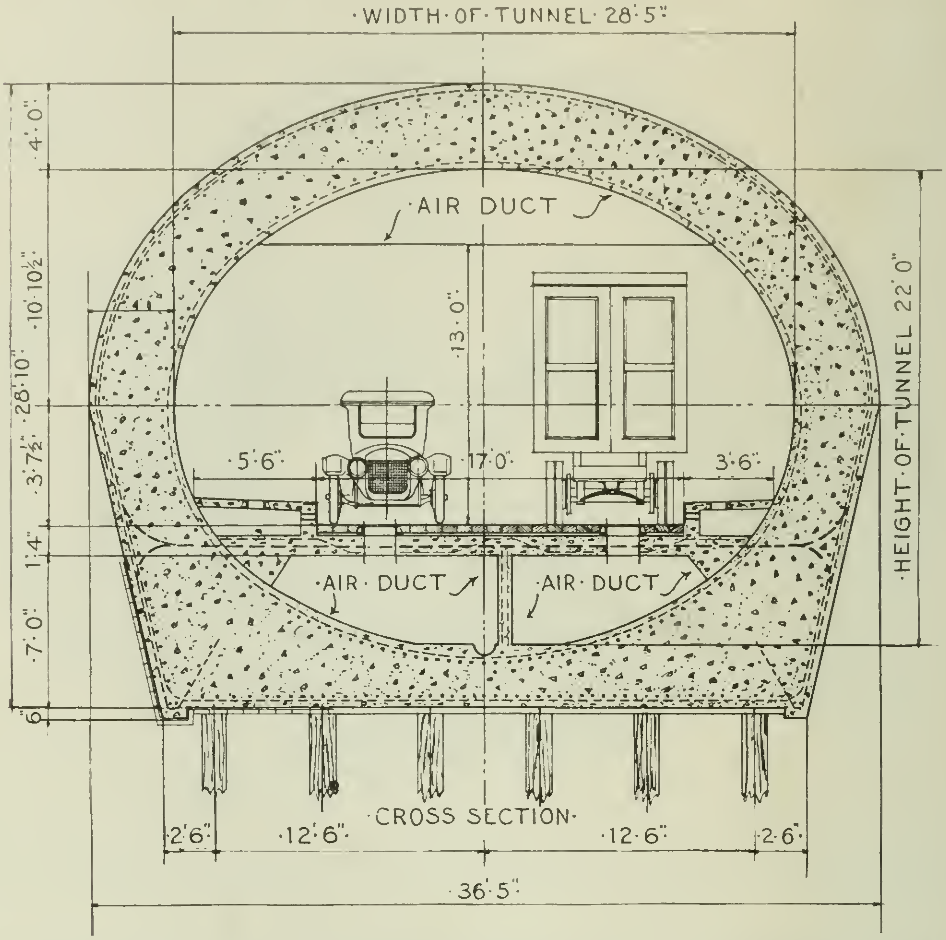


CROSS SECTION.

Proposed highway tunnel between Canal Street, New York, and 12th Street, Jersey City. (*Goethals.*)

The remaining portions of the tunnel, between the portals and the river sections on each side of the river, were to be constructed by the open or the pneumatic caisson method. The advantage claimed for the trench method of construction was economy and least depth below mean low water, which was figured for the first time by the Government at fifty feet.

In connection with the report of Public Service Corporation, the board of engineers made a special investigation of tunnel ventilation. Some engineers had doubted the practicability of operating a tunnel of the length proposed for motor vehicles on account of the danger of carbon-monoxide in the exhaust gases, although it had already been pointed out by Messrs. Jacobs & Davies in their report that mechanical ventilation was feasible.



Proposed highway tunnel between Canal Street, New York, and 12th Street, Jersey City. (*Burr, Modjeski and Moran.*)

Assuming that all other engineering problems, such as construction and drainage, could be overcome if it were impossible to remove or dilute the poisonous gases, it was evident that the entire project would have to be abandoned. Up to the time the preliminary study of the tunnel was undertaken very little information was available concerning waste from gas engines, although all other information (such as proper proportion of air to gas for perfect combustion) was readily obtainable. Fatalities, due to exhaust gases in garages, are becoming quite common, and this may cause more interest in the general subject of exhaust gases in the near future.

In considering the ventilation of the tunnel, the number of cars that might be in the flume at any one time could be assumed; likewise the average horsepower per motor, the speed at which the car would run and the average mileage per gallon of gasoline. So it was quite an easy matter to calculate the quantity of fresh air necessary to take care of the operation of the motors. At the same time it was necessary to ascertain how much air should be exhausted and how much air supplied per minute to make the air livable and to overcome the poisonous carbon-monoxide.

Various authorities have advanced different ideas as to the proper quantity of air to be supplied and exhausted, and some have gone so far as to say that it is impossible to ventilate a tunnel of this kind at all.

Four different schemes were given consideration for the ventilation of the tunnel:

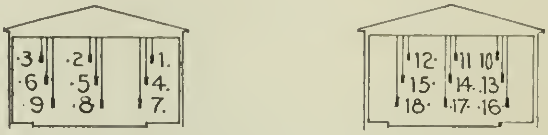
First: Utilizing the suction of cars running through the tunnel. This idea was abandoned when the neutralizing effect of cars running in opposite directions was considered.

Second: Forcing large quantities of air in one end of the tunnel and exhausting at the other. This was eliminated when it was considered that the total exhaust gases in the tunnel would be forced to one end and would probably make the air at that point quite dangerous.

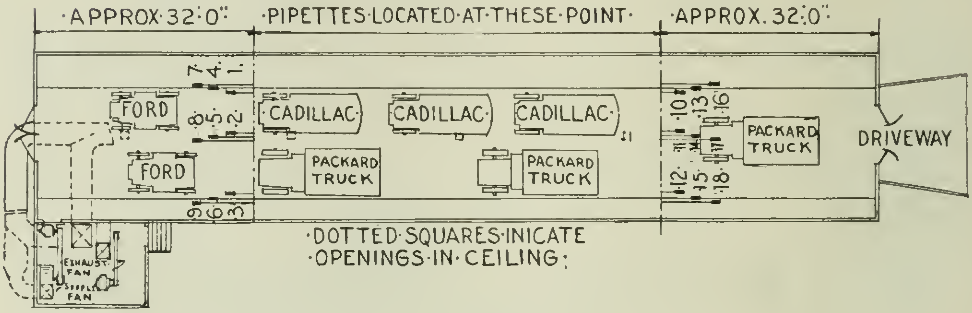
Third: Installing an exhaust system drawing all air from the tunnel and allowing fresh air to come in at the portals and through fresh air shafts which would be built at the bulkhead line on both shores of the river. This scheme was also considered impracticable when it was found that the condition would be similar to Scheme No. 2, except that considerable of the foul gases would be drawn to the centre of the tunnel, with very little fresh air to dilute them.

Fourth: To install a system of both supply and exhaust fans and ducts, with inlet and outlet openings at various points, so that the tunnel could be theoretically blocked off into sections, each section having its separate inlet and outlet opening. This plan was finally adopted.

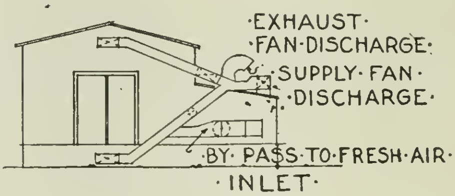
With Scheme No. 4 arose the same old question as to the proper quantity of air necessary for both supply and exhaust. As before mentioned, little was known about the properties of exhaust gases, and, therefore, no stated quantities could be decided upon. For this reason the engineers decided to erect a test building of the same cross-sectional design and dimensions as the proposed tunnel and of sufficient length to enable a number of cars to enter, and then to install a ventilating system of such nature that the same could be increased or decreased in capacity as occasions might demand.



Section showing location of pipettes from front (east) end of building.



PLAN.



END ELEVATION.

Sketch showing location of pipettes for gas analyses and various automobiles and trucks during tests at Experimental Building, Passaic wharf, Newark, N. J.

Accordingly, a building 125 feet in length, twenty-five feet in width and fifteen feet in height was constructed on the Passaic Wharf property of Public Service Railway Company at Newark. The cross-section of the building was an exact duplicate of the interior of the proposed tunnel. The interior of the building was lined with beaver board so that a smooth and uniform surface was obtained. When the doors were closed the building was practically airtight. Over the ceiling and under the floor spaces were left for ventilating ducts, which were installed and supplied with a number of openings controlled by dampers. The openings in the ceiling were twenty-five feet on centres, while the openings at the floor, which were in both the curb and walkway, were twelve and one-half feet on centres, placed diagonally opposite each other. The ducts were cross-connected at the rear of the building, so that the system could be interchangeable if required. The ducts were then brought down to exhaust and supply fans, which were installed in a small shed at one end and at the side of the building. These fans were built by the Buffalo Forge Company of approximately 15,000 cubic feet of air per minute capacity, and were belted to direct current variable speed motors, which in turn were controlled by regulators, so that the speed and capacity of the fans could be varied as desired. In this fan room were also installed two Ellison draught gauges, one for each fan, so that constant readings as to the volume of air handled and frictional resistance could be carefully tabulated.

In the building, or improvised tunnel section, were operated eight automobiles, comprising two Ford Roadsters, three Cadillac Touring cars and three Packard trucks, which would give about the same conditions as would be found in a section of the tunnel if it were actually constructed.

There were various tests made, as follows:

1. Cars running normally, with no ventilation.
2. Cars racing, with no ventilation.
3. Cars running normally, with air being blown in at ceiling and exhausted at floor.
4. Cars racing, with air being blown in at ceiling and taken out at floor.
5. Cars running normally, with air being blown in at the floor or road line and exhausted at ceiling.
6. Cars racing, with air being blown in at floor line and exhausted at ceiling.

Chemical analyses of contaminated air were undertaken by Prof. Gellert Alleman, of Swarthmore, Penna. He was aided by Dr. H. Jermain Creighton, Assistant Professor of Chemistry, Swarthmore College, and Messrs. R. L. Hill and L. T. Sherwood.

It was considered necessary to make accurate determinations of the contaminated air near the floor, ceiling and the sections intervening between the floor and the ceiling. The contaminated air was collected in cylindrical pipettes over mercury. These pipettes were twenty-two centimetres long and four centimetres in diameter, and had a volume of approximately 250 cubic centimetres. Each pipette held about eight pounds of mercury. The pipettes were closed at each end by a glass stopcock. In order to prevent the pipettes from breaking under the weight of mercury when suspended for collecting samples, each pipette was suspended with a heavy canvas jacket to the top of which a loop of wire was attached. Eighteen pipettes were used in the experimental tunnel at one time. Nine of these were suspended one-quarter the distance from either end. Each set of nine was arranged as follows: three midway between the top of the tunnel and the bottom, and three at one-quarter the distance from the roof and the floor.

After the engines of the automobiles had been operated for a definite length of time a number of men entered the experimental tunnel, opened the top stopcock of the pipettes, placed pitchers under the bottom stopcock and then opened the latter, allowing the mercury to flow into the pitchers. As the mercury ran out the pipettes were filled with the air and other gases in the tunnel. When the mercury had left the pipettes both stopcocks were closed. In this way eighteen samples of the contaminated air at a like number of points uniformly distributed throughout the tunnel were obtained for each test. These samples were then analyzed.

Solutions were employed for the absorption of the components of the contaminated air to determine the relative quantities of the following:

1. Carbon dioxide.
2. Unsaturated hydro carbons.
3. Oxygen.
4. Carbon monoxide.

The residue unabsorbed was assumed to be nitrogen.

From a very elaborate and convincing analysis Professor Alleman reported that when all doors were closed and the ventilators open and exhausting from the top of the tunnel, and after the engines of eight cars had been "running light" for forty minutes, the condition of the atmosphere was almost normal so far as physiological action was concerned and the carbon-monoxide content not dangerous. This conclusion was further supported by the fact that the eighteen persons who remained in the tunnel during the test for a continuous period of forty minutes experienced no unpleasant sensations from breathing the air and no subsequent distress.

The contaminated air analysis for this particular test was as follows:

Unsaturated hydro carbons	0.01 per cent.
Carbon dioxide	0.06 per cent.
Oxygen	20.54 per cent.
Carbon monoxide	0.075 per cent.

which proved that the percentage of carbon monoxide was so small as to be negligible.

From the data obtained it was figured that supply fans with a maximum capacity of 360,000 cubic feet of fresh air per minute and the exhaust fans some twenty per cent. more capacity would be required to ventilate the tunnel. In all it was figured to provide a maximum of 750 horsepower to operate these fans and the maximum static pressure that the supply fans would be required to operate against was five inches to six inches.

The system of exhaust and supply fans in the tunnel was to operate from four stations:

> One to be situated between the portal and the fresh or foul air shafts (built at the bulkhead line) on the New Jersey side and ventilating this approach only.
>
> One at the base of the New Jersey shafts and ventilating that portion to the centre line of the tunnel.
>
> One station on the New York side, duplicate of that at the base of the New Jersey shafts.
>
> One midway between the New York shafts and the New York portal, ventilating this approach only.

The first, second and third stations were to be equipped with both supply and exhaust fans, and the fourth station, or that on the New York approach, was to have exhaust fans only, since this approach was but 1400 feet long.

The fans at the various stations were to be made up of several small units so that air quantities could be varied according to the traffic and thereby keep down the cost of ventilating to a minimum.

In the early part of the year 1917 Mr. Thomas N. McCarter, President of the Public Service Corporation of New Jersey, made public the tunnel report, hereinbefore referred to, which had been prepared for that Corporation by experts retained by it. The Company's purpose, as explained by Mr. McCarter, was not to advocate any special plan but to demonstrate the feasibility of a tunnel from practical engineering and financial standpoints and to urge that one be constructed as soon as possible by the States of New York and New Jersey. His idea was to show that if the tunnel were not operated as a free public highway, similar to the bridges over the East River, it could be profitably operated as a private enterprise and that highly favorable results would be obtained.

He explained that his corporation had no selfish interest in the proposition as a profit-bearing utility, but was heartily in favor of the project, because it would spell progress for metropolitan New York and the whole State of New Jersey. All of the data obtained by the corporation at its own expense were placed gratuitously at the disposal of the Interstate Bridge and Tunnel Commission, and the public authorities were put on notice that if the governmental agencies did not act within a reasonable length of time after the return to normal business conditions, the corporation would seek State authority to finance and operate the project on its own account, charging tolls as a means of reimbursing itself for its investment.

Since that time, as well as before, the proposition has been given serious consideration by the Interstate Bridge and Tunnel Commissions of New York and of New Jersey. In New Jersey legislation has been enacted to enable the State to join with New York in the construction and operation of a tunnel. Like arrangements are under consideration by the State of New York. Besides, there is a bill now before Congress that provides for $6,000,000 as the Federal Government's contribution toward the construction of this tunnel.

It is hoped with peace at hand and industrial conditions readjusting themselves, this much needed improvement, that will affect the convenience, the comfort and the cost of living of 7,000,000 inhabitants, will be carried to fruition.

THE VISIBILITY OF AIRPLANES.*

BY

M. LUCKIESH.

Physicist, Nela Research Laboratory.
National Lamp Works of General Electric Co.

1. FOREWORD.

The object of the investigation described below was to analyze the various aspects of the visibility of airplanes, to ascertain the possibilities of attaining low visibility in various phases of airplane activities, to arrive at specific practical recommendations, and to eliminate guesswork by supplying a scientific foundation consisting of measurements for the solutions of the problems involved in obtaining low visibility. The war closed before some of the many interesting details could be thoroughly unraveled, but the fundamental data upon which the attainment of low visibility for airplanes may be founded, are presented in this paper. The work was conducted primarily for the Science and Research Division of the Bureau of Aircraft Production from whom permission for publication has been granted. The original reports contained a number of illustrations in color which will not be reproduced in this paper. Furthermore, it does not appear profitable to present all the details of the original discussions and recommendations.

2. INTRODUCTION.

We distinguish objects through differences in light, shade, and color, or, in other words, through differences in brightness and color. Form is sometimes included in such a statement, but this is unnecessary inasmuch as form is determined by the distribution of light, shade, and color. If, then, an object is seen and recognized owing to a distribution of brightness and color which is different from that of the surroundings, it follows that it will be invisible if no such differences exist or the object will be of low visibility if these differences are minimized. In striving for low visibility we must strive for distributions of brightness and color in the object similar to that of its environment or the background against which it is viewed.

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* Based on a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, January 9, 1919.

Many decades ago we learned lessons from nature in the art of concealing coloration and one of the fundamental precepts of Nature's camouflage is that an object of a uniform brightness and color is not as inconspicuous amid the usual natural environments, in which variety in light, shade, and color is infinite, as an object of broken color and brightness, in which the average hue and the average brightness approximate those of the environment. (See Reference 1.) Hence pattern is nearly always an essential feature of successful camouflage. An exception is such a case as a uniform blue sky for a background.

We have learned this lesson in certain types of camouflage and should apply it in certain types of camouflage for aircraft. Invisibility is the dominant note of land camouflage. Invisibility was for some time the chief aim of marine camouflage but the submarine menace with its short range of effective attack has caused "confusibility" to replace "invisibility" for the protection of many vessels. In the case of a submarine attack, for example, on a vessel a mile distant there is no possibility in ordinary weather for "invisibility" to save the vessel. However, "confusibility," by rendering it difficult or even impossible for the submarine commander to judge the exact course of the intended victim, may result in a miss, which, according to the old adage, "is as good as a mile."

The program of study of airplane camouflage included chiefly two general viewpoints, namely, above and below the airplane for invisibility. Unfortunately the solutions of these two problems are usually more or less opposed to each other. When viewing the craft from underneath, the background is the bright sky and clouds whose aspect changes sometimes from minute to minute, and when looking down upon the airplane the background is usually the much darker earth whose aspect changes from season to season, owing to the variation in the earth's cloak. The sky is a uniform background only on a cloudless day or on a perfectly overcast day. A clear blue sky and a dense overcast sky are of lower brightness than sunlit clouds and hazy or lightly overcast skies. A sunlit cumulus cloud will often be many times brighter than an adjacent patch of blue sky. The greatest difficulty, however, is due to the extremely greater brightness of the sky than that of objects in the air as seen from below.

Obviously the character of camouflage which is predominantly required will depend upon the type of airplane, such as bomber, scout, chasse, patrol, etc.; upon the height at which various aerial operations are carried out, and upon various other characteristics of service.

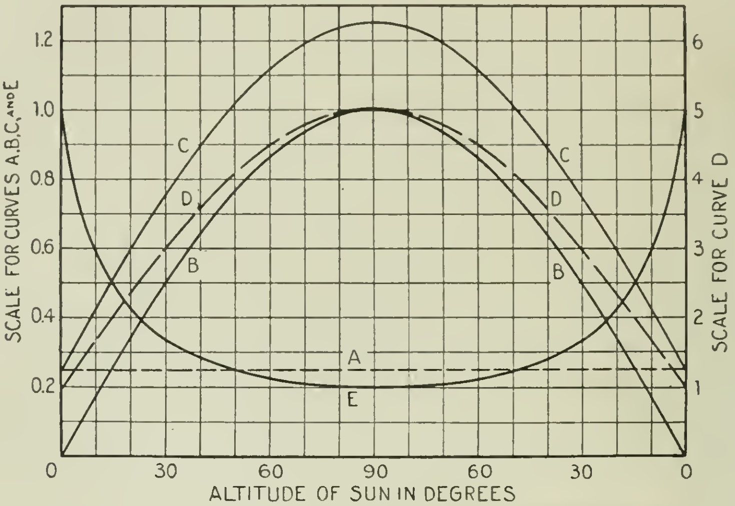
3. MEASUREMENTS AND OTHER OBSERVATIONS.

It becomes evident early in the consideration of the problem of lowering the visibility of airplanes that various measurements could be readily obtained which would provide a firm basis for the actual work. In all branches of camouflage there has been much time and energy wasted in speculation and experiments which scientific investigation would have eliminated. In fact, the only certainties in some branches of camouflage have been established by scientific investigations. The final steps in reducing the visibility of airplanes must necessarily be compromises as is the case in most practical problems, but the writer feels assured that the data herein recorded provide a definite basis for practical work and successful camouflage. In fact, without such data the final practical steps must rest entirely upon the qualitative data obtained by individual judgment and we could not be assured of having adopted the best procedures within months and even years of cumbersome experiments. Therefore, the writer directed his first efforts toward obtaining measurements and making other observations which would establish:

1. The relative brightness or apparent reflection-factor of various earth areas.
2. The mean relative brightness or apparent reflection-factor of the earth.
3. The mean relative brightness of water areas.
4. The mean hue of the earth areas.
5. The mean hue of water areas.
6. The size of pattern for airplane camouflage.
7. The shape of pattern for airplane camouflage.
8. Certain brightness measurements in terms of the brightnesses of the sky and of clouds.

The measurements and observations presented in the following may not, in all cases, appear to be of direct interest in solving the problems which have been attacked, but a detailed knowledge of these various aspects is essential for obtaining a full grasp of the possibilities and expedients to be adopted in rendering airplanes of low visibility in general. Thousands of measurements have been made but these will be presented in condensed form. Numerous cross-country flights were made besides many short flights on various types of days and under various natural lighting conditions—a total of 60 hours of flying, or about 5000 miles of air travel having been devoted to the work. Most of the work was carried out at Langley Field, Hampton, Va., but cross-country flights were made from this point to Washington and Richmond, and over the Chesapeake Bay and Atlantic Ocean.

FIG. 1.



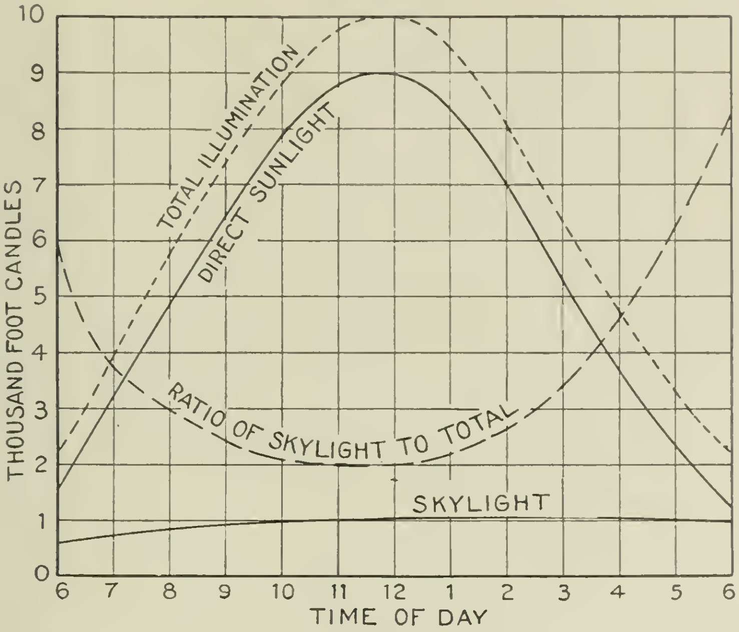
Theoretical relations of the illumination intensities of sunlight and skylight on a horizontal plane.

4. SOME THEORETICAL CONSIDERATIONS.

Before presenting the measurements which have been made and the final discussions of the possibilities of obtaining low visibility a few theoretical and practical aspects will be discussed.

The relation of sunlight to skylight is theoretically considered in Fig. 1 (see Ref. 2). For this purpose the brightnesses of a horizontal white diffusing surface and a shadow upon this surface may be determined. The light from a clear blue sky does not vary greatly in intensity during a considerable portion of the day. However, the amount of direct light from the sun falling upon a horizontal surface varies from zero at sunrise to a maximum at noon and at zero at sunset. For the purpose of discussion the illumination upon a horizontal surface due to direct sunlight at noon is assumed to be four times that due to light from the sky, and for simplicity the amount of light from the sky is assumed to be constant from sunrise to sunset. The illumination intensities due to the sun and sky respectively under the assumed conditions are shown in Fig. 1, curve A being the constant illumination due to the sky and curve B the illumination due to the sun throughout its entire range of altitudes, which is represented on the horizontal scale. Curve C represents the combined illumination from sun and sky. The vertical scale for curves A, B and C is on the left of the figure. The broken curve D represents the ratio of the combined illumination due to the sun and sky to that due to the sky alone; that is, it represents the ratio of the brightness

Fig. 2.

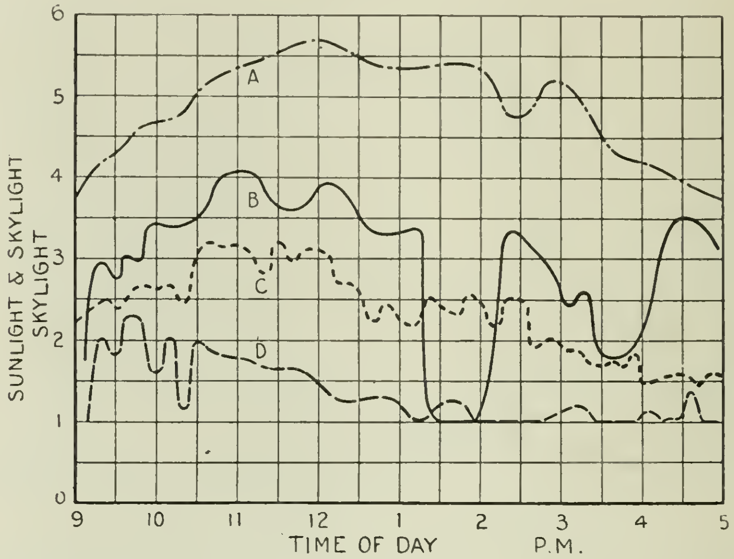


Relations of illumination intensities of sunlight and skylight on a horizontal plane on an extremely clear day.

of the test surface receiving the combined light from the sun and sky to the brightness of a small shadow upon the surface which receives only skylight. In other words, it is obtained by dividing the ordinates of curve C by those of curve A and the values of this ratio are represented on the vertical scale at the right. Curve E is the reciprocal of curve D; that is, it represents the ratio of the brightness of the shadow on the test surface to that of the surrounding portion of the test surface which is illuminated by light from both the sun and the sky. Its vertical scale is on the left of the figure. While natural conditions will not be found to be so uniform throughout an entire day, the data shown in Fig. 1 are interesting and useful for obtaining an idea of the natural lighting conditions on a clear day. The data obtained on clear days do not differ very much from the theoretical curves of Fig. 1. In Fig. 2 are represented the conditions on an extremely clear day.

Representative data are presented in Fig. 3 for four characteristic days. The measurements were made continually from 9 A.M. until 5 P.M. Curve A represents the ratio of the brightness of the surface receiving both sunlight and skylight to the brightness of a small shadow on the same surface which receives only skylight on a very clear day. The sky was a deep blue and no definite clouds appeared during the entire period of eight hours—a very rare condition in most localities. It will be noted that during midday the skylight was only one-fifth to one-sixth as intense as the combined intensity of sunlight and skylight. In other words, during midday the sun contributed about four or five times the amount of light that the sky contributed on this clear day. At observatories, high in the mountains, on very clear days it has been found that as little as one-tenth the light which reaches the earth comes from the sky, the remaining nine-tenths coming directly from the sun. The tendency for the ratio to increase toward noon corroborates the conclusions arrived at in the theoretical treatment of the conditions on a clear day, as shown in

Fig. 3.

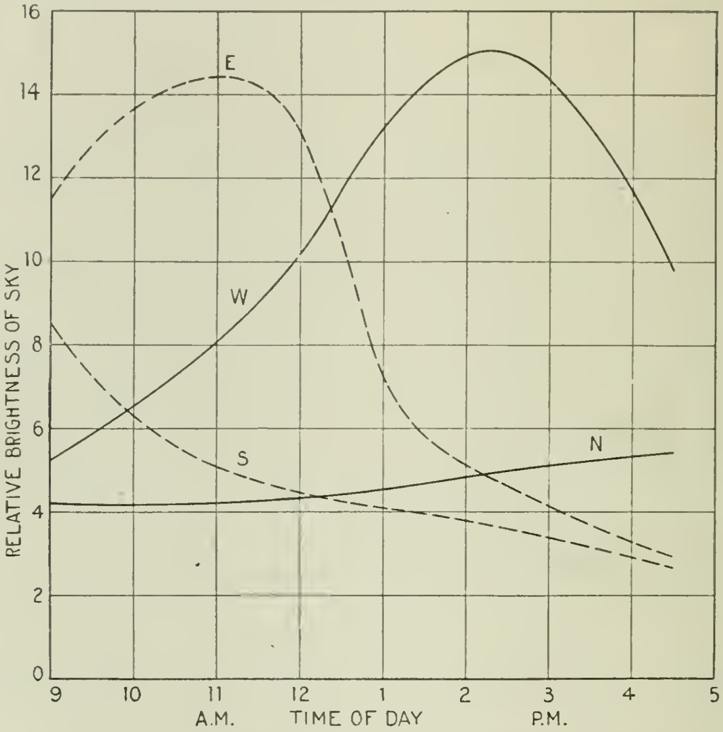


Ratio of total illumination on a horizontal surface outdoors to that due to skylight alone on various days.

curve D, Fig. 1, and also in Fig. 2. It should be noted that these observations did not extend from sunrise to sunset, which was the time interval used in the theoretical discussion in Fig. 1. Curve B in Fig. 3 represents data obtained on a day during the morning of which a few large cumulus clouds moved slowly across the sky. The sunlight reflected from these clouds increased the relative amount of diffused light, or light from the sky, with the result that the ratio under consideration was smaller than on a clear day. About 1.30 P.M. massive clouds obscured the sun, so that for a time no shadow was perceptible upon the test surface and the ratio became equal to unity. During the remainder of the afternoon the moving clouds caused considerable variation in the ratio. It should be noted that sunlit cumulus clouds are very much brighter than a clear blue sky. Curve C represents data obtained on a thinly overcast day. The sun was plainly visible, but the sky was overcast with a thin hazy veil and therefore was brighter than a blue sky, with the result that the relative amount of skylight increased and the ratio under consideration was much smaller than on a clear day. The hazy veil grew thicker and therefore brighter as the day progressed, with the result that the ratio gradually decreased. Curve D represents data obtained on a day during the afternoon of which the sky was quite completely overcast. During the forenoon the sky was covered with broken clouds, but these became welded into a uniform covering about noon, with the results as shown. Thus, results obtained on four distinctly different types of days are shown in Fig 3, and the data give some idea of the tremendous variations in the distribution of natural light outdoors. Absolute intensities of natural light have not been considered in the foregoing, because they are of minor interest.

Inasmuch as the sky is usually a prominent feature, a few facts regarding it may be of interest. Except at altitudes near that of the sun, a clear blue sky is usually considerably brighter at the lower altitudes—near the horizon—than at the zenith, due largely to the greater haziness noticeable at the lower altitudes. This is perhaps always true, excepting when dense clouds, which are not recognized as clouds, are gathering near the horizon. A clear blue sky is darker than an overcast sky except in the extreme cases of the latter. A slight haze or thin veil of clouds increases the brightness of the sky very much and therefore increases the amount of light which illuminates many shadows. The color of the sky when clear is more saturated than under any other condition, varying from this deep blue to the neutral gray of an overcast sky. The extreme non-uniformity of the brightness of clear blue or overcast skies is only revealed by measurement. Often a sky which appears quite uniform will vary in brightness at different points by several hundred per cent. A clear sky is usually brightest at those altitudes near the sun, which becomes more marked on hazy days when the atmosphere contains more reflecting particles. This is illustrated by means of Fig. 4, the data shown having been obtained on a clear day when the sky was very slightly hazy. The letters on the four curves stand for east, west, north, and south respectively. The brightness of portions of the sky, about 20 degrees above the horizon and approximately at the four points of the compass, were measured during a day in August from 9 A.M. to 5 P.M. at a point near 40 degrees north latitude. No definite clouds were visible during the period of observation. It will be noted that the brightness of the sky was greatest in the east in the morning and greatest in the west

Fig. 4.



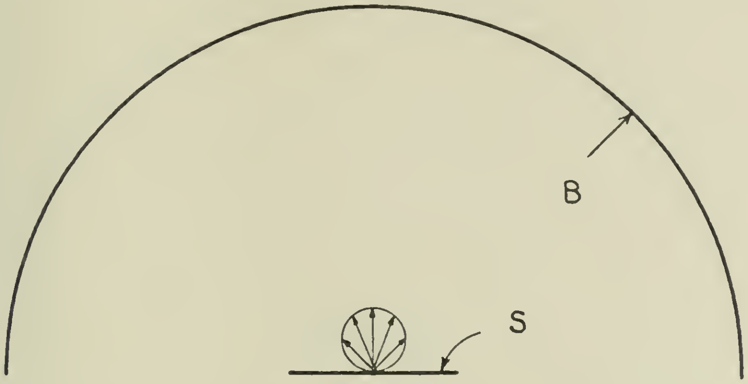
Variation of the brightness of the sky throughout a clear day.

during the afternoon. On a perfectly clear day when the sky was a deep blue, the variations of sky brightness were not so great. The recognized constancy of north skylight is also shown in this illustration.

In dealing with the problems of lighting it is necessary to distinguish between illumination and brightness (cause and effect respectively); to appreciate the difference between the conditions and effects on sunny and overcast days; and to be familiar with certain characteristics of reflecting and transmitting media.

If a hemisphere (Fig. 5) of uniform brightness B is solely responsible for the illumination of the surface S, the brightness of S will equal B if S is perfectly reflecting. Furthermore, this would hold if S were either a polished or a diffusing surface. Inasmuch as the reflection-factor R of a surface is never unity, the brightness of the surface S under the above conditions is equal to RB. If the object were perfectly transparent, obviously the brightness B would be seen through the object, but if it had a transmission-factor of T then the brightness as seen through the object would be reduced to TB.

FIG. 5.



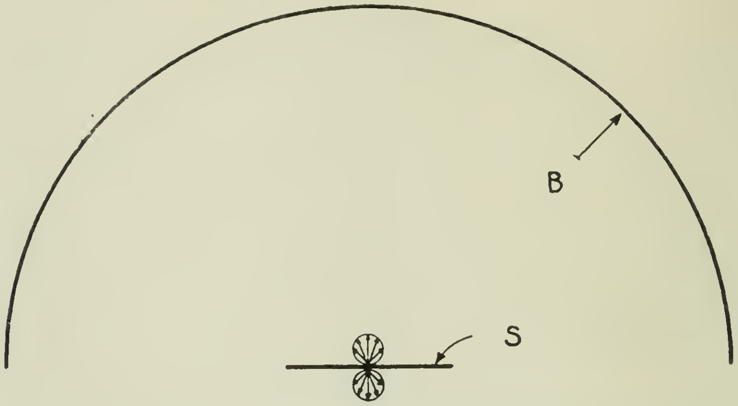
Diffusely reflecting surface S illuminated by hemisphere of brightness B.

If the object were perfectly diffusely transmitting, its brightness would be only 0.5 B because one-half the incident light is diffused back toward the hemisphere as indicated in Fig. 6. The foregoing condition is representative of that on a perfectly overcast day or before sunrise and after sunset. Obviously the upper limit of brightness in the case of diffusely transmitting media is only one-half that of reflecting media.

At noon on clear days the illumination of a horizontal surface is due chiefly to direct sunlight. Of course the ratio of direct sunlight to skylight at the earth's surface varies considerably owing to clouds, haze, etc., but of the total light reaching the earth's surface at noon the direct sunlight constitutes as much as 0.9 on extremely clear days. A common value is in the neighborhood of 0.8. This has an intimate bearing upon the visibility of airplanes as viewed from below.

In Fig. 7 we have reproduced the conditions of Fig. 5 with the superposition of direct sunlight at midday. The hemisphere may be considered to represent the sky of brightness B. If the surface S is perfectly diffusely reflecting, its brightness due to the skylight alone is B. Its brightness due to the direct sunlight alone we will assume to be 4 B, which is a fair average. Hence we would have a total brightness of 5 B. If the reflection-factor of the surface is equal to R, then the total brightness is 5 RB.

FIG. 6.

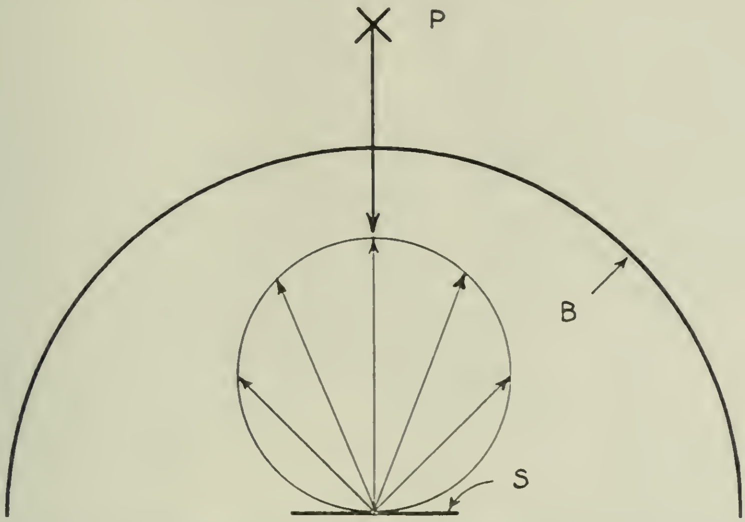


Diffusely transmitting thin object S illuminated by hemisphere of brightness B.

Assuming the object to be perfectly diffusely transmitting, its brightness would be 2.5 B and, therefore, when viewed against the sky it would appear 2.5 times as bright as the sky. Ordinary translucent media are far from perfectly diffusely transmitting, hence the brightness is 2.5 TB, where T is the transmission-factor. If T were equal to 0.4, under the conditions assumed, we would have the brightness as viewed from below equal to $2.5 \times 0.4 \times B = B$. In other words, if the object were diffusely transmitting with $T = 0.4$ on a clear day when the sun contributed 0.8 of the total light on a horizontal surface at midday, this translucent object, as viewed from beneath, would be of the same brightness as the sky. However, it would not be invisible, because it would appear yellowish in color owing to the fact that most of its brightness is due to sunlight which is yellow in contrast with the blue skylight. The medium may be colored a blue tint to counteract this. (See Ref. 2, Chapter VII, and Ref. 3.)

This discussion is introduced at this point to indicate reasons for obtaining the measurements which are presented in some of the sections which follow. It is resumed again (Secs. 15 and 16) in connection with the practical considerations of low visibility for airplanes which are treated in later sections.

FIG. 7.



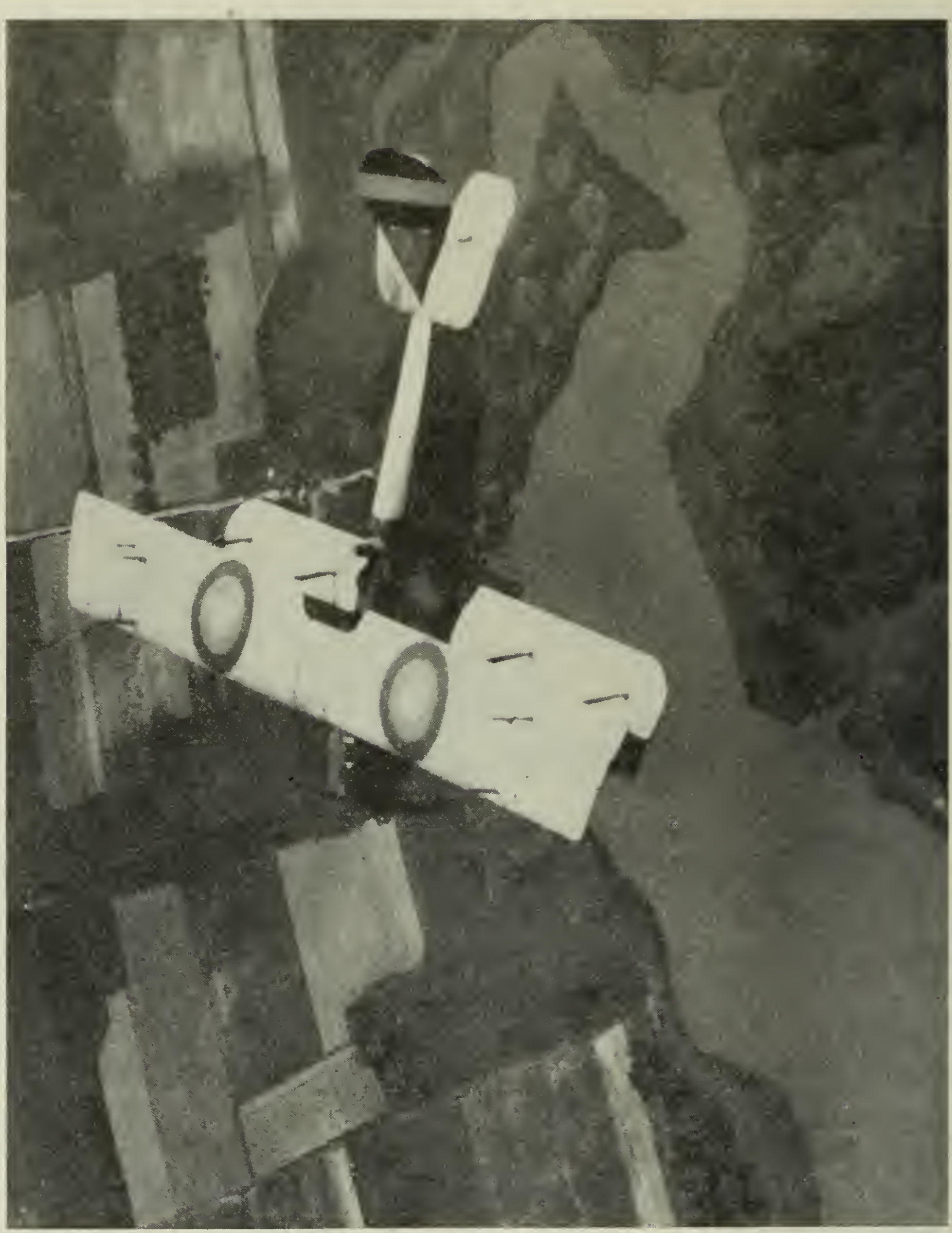
Diffusely reflecting object S illuminated by hemisphere of brightness B and by a point source of light P. Simulating conditions at noon on a perfectly clear day when sun is contributing 0.8 of total light.

5. RELATIVE BRIGHTNESS OR APPARENT REFLECTOR-FACTOR.

To apply the term reflection-factor (commonly called reflection-coefficient) to the earth's surface which has "depth" is somewhat misleading; however, as viewed from an appreciable distance above the earth, this term is not misapplied from a practical standpoint. The term "relative brightness" will be used occasionally and, unless otherwise stated, will mean the brightness relative to a perfectly reflecting and diffusing opaque surface under the same illumination. Obviously the reflection-factor of this theoretical white surface is equal to unity so the values of "relative brightness" may also be considered "apparent" reflection-factors.

In the following table the individual values are means of many observations, and a sufficient number of these are presented to show the consistency of the results. All were made within 150 miles of Langley Field. Further comment on these various types

Fig. 8.



Illustrating character and approximate relative brightness of typical earth areas.

of areas will be found in following sections. Measurements, unless otherwise stated, were made vertically downward from the airplane and usually at altitudes from 1000 to 5000 feet. The brightness measurements were made with different types of instruments in terms of the brightness of a white diffusely reflecting (or transmitting) surface receiving the same illumination. These values were then reduced to values in terms of a perfect white. Obviously such measurements had to be made below the clouds when the latter were present. Many measurements were made at various altitudes up to 20,000 feet, although for earth measurements the effect of the low-lying haze was reduced to a minimum by making the measurements vertically downward and at low altitudes. Most of the measurements were made during the middle of the day because instrumental errors were less at this time. However, no extensive differences were obtained in the results

TABLE I.

Relative Brightnesses or Apparent Reflection-Factor of Various Types of Earth Areas in Per Cent.

(These were determined in eastern Virginia within 150 miles of Hampton. In all cases the surfaces were viewed from points directly above them, varying from an altitude of 1,000 feet upward. The individual values in the following table are means of numerous measurements. In some cases hundreds of measurements were made during a single flight.)

		Fields	Barren Land	Woods	Inland Water
Aug. 30, 11 to 12.	Generally clear	7.4	10.4	4.9	5.7
Aug. 30, 2 to 3.	Sunny with large clouds scattered	9.3	10.3	4.9	9.0
Aug. 31, 11 to 12.	Generally clear, some thin hazy clouds	6.1	10.1	4.4	6.7
Aug. 31, 1 to 2.	Fairly clear, some clouds	5.8	11.1	3.8	6.2
Sept. 3, 11 to 12.	Sunny, with large scattered clouds	7.9	15.9	3.9	6.3
Sept. 3, 1 to 2.	Generally clear	7.0	19.0	4.6	7.1
Sept. 3, 3 to 4:30.	125-mile trip across country east and south	6.8	17.1	5.0	6.2
Sept. 4, 11 to 12.	175-mile trip to Richmond, Petersburg and return	6.5	13.8	4.5	7.4
Sept. 6, 11 to 12.	Overcast sky	6.7	13.6	4.4	9.1
Sept. 7, 1 to 2.	Clear day	6.3	....	...	7.6
Sept. 9, 11 to 12.	Clear day	...	11.2	3.6	6.7
Sept. 9, 2 to 3.	Clear day	6.7	14.2	3.9	4.4
Sept. 10.	On trip to Washington and return	5.2	8.7	3.5	5.2
	Mean	6.8	1.30	4.3	6.8

Shadow of cloud on earth's surface is less than 1 per cent. Dense clouds up to 78 per cent.

at various times of the day or even on sunny and overcast days. In Fig. 8 is seen a fairly satisfactory photographic reproduction of the relative brightnesses of the various types of areas represented in Table I. A close study of this photograph with the mean values of the Table I in mind is quite interesting.

6. LANDSCAPE.

During the period in which the foregoing observations were made the landscape was still predominantly green, although in some areas there was a slight tinge of yellow common to late summer. It seems reasonable to assume that this season of the year represents a fair mean of the conditions during the chief period of active warfare in this zone. There were many ploughed fields barren of vegetation and others which were not entirely covered by green foliage. In the territory of eastern Virginia there is a great deal of wooded country including wooded swamps, so it appeared, among other reasons, best to keep separate records for the different types of earth areas. Furthermore, there are various kinds of soil, so that the variations in the values in Table I are to be expected. However, the consistency of the observations on woods and fields covered with crops and also on water was surprising. The greatest variations were found for barren land.

The mean relative brightness or apparent reflection-factor for a landscape will depend upon the proportions occupied by the various types of areas. This is another reason for obtaining mean values for the various types of areas. It may be of interest at this point to refer to some of the photographs of landscapes which are included in this paper.

Attempts were made to estimate the proportions of different types of areas present in the landscapes studied. This could be fairly accurately determined for any given part of the country by cross-country flights, during which a record of time in passing over the various types of areas could be kept. If the airplane speed were approximately constant this would give a fairly satisfactory mean value for the relative brightness or the apparent reflection-factor of the terraine. This was done a number of times. For example, the mean value obtained during a 175-mile trip from Langley Field to Richmond to Petersburg and return was about 7 per cent. However, it should be noted that this portion of the country contained much wooded area, although the course was generally maintained over the more cultivated regions.

Notwithstanding the writer's familiarity with brightness measurements of landscapes, the generally low values obtained in this investigation were surprising. However, these may be accounted for by considering the earth's surface more in detail. On looking down upon such areas as fields, woods, etc., one sees a mixture of highlights and shadows. Much of the area receives only skylight which is only a small part of the total light reaching the earth on sunny days. Even on overcast days the shadows receive only a small portion of the total light reaching the earth's surface. For example, a grass area possesses " depth " similar to velvet. Black velvet has a very low reflection-factor (about 0.4 per cent.), but ordinary blotting paper colored with the same dye will possess a diffuse reflection-factor of about 2 per cent. The depth of the velvet fibre provides light traps and shadows with the result that the reflection-factor as a whole is much lower than that of a single fibre. In a similar manner grass plots, cornfields, ploughed ground and woods provide light traps and shadows so that the mean brightness or apparent reflection-factor is materially reduced.

For example, let us assume that the reflection-factor of a blade of grass is 0.16; that the sun contributes 0.8 of the total light; and that the normal aspect of the grass plot is one-half shadow and one-half highlight. If the brightness of the sky is equal to B, then the brightness of a perfectly white horizontal reflecting surface will equal B, due to skylight alone, and equal to $5\ B$, due to sunlight and skylight. The brightness of the blades of grass receiving both skylight and sunlight will be $5\ B \times 0.16 = 0.8\ B$. The brightness of the grass in shadow, assuming the shadows to receive full skylight (they actually receive much less), will equal $0.16\ B$. The mean apparent brightness will be equal to ½ $(0.8 + 0.16\ B)$. The mean apparent reflection-factor would then equal $\frac{0.48\ B}{5\ B}$, or 0.1 approximately. Thus it is seen, with these assumptions, the apparent reflection-factor of the grass plot as a whole is much less than that of individual blade which was assumed to be 0.16. It will also be noted that the trapping of light by virtue of the " depth " of such a surface was not considered in the foregoing analysis. Woods are strikingly dark owing to these reasons, and on the whole these considerations prepare us to expect a surprisingly low mean apparent reflection-factor of the earth. Bare earth which has been packed by rain and baked by the sun is conspicuously brighter than the same soil freshly ploughed even after the latter has dried. It is commonly noted that wet dirt is darker than the same dirt when dry. For example, a blotting paper which, when dry, reflected 0.74 of the incident light, reflected only 0.54 of the incident light when wet. The brightness of all earth areas does not vary much with the angle at which they are viewed. This is not strictly the case with the surface of water as will be noted later.

Although an overwhelming number of the values of apparent reflection-factor or relative brightness are included within a range from 3.5 per cent. to 10 per cent., the following ranges include practically all the values obtained for the different types of areas:

Ploughed and barren ground	0.10–0.20
Grass, fields	0.05–0.10
Woods	0.03–0.05
Inland water	0.05–0.10

The values for water are included here for the sake of interest, but owing to the special character of its surface reflection it is discussed at length in Section 9.

The change in Nature's cloak during the various seasons must be considered, but the most intensive activities in warfare are carried on from spring to fall usually and, therefore, the summer garb of Nature is here considered of chief importance. The reflection-factor of snow can be assumed to be equal to that of commercial white pigments and the values for barren ground in Table I will hold for winter. It would not be difficult to make a fairly accurate estimate of the apparent reflection-factors of various types of areas for late autumn after the experience accumulated in the present investigation. From such values fairly successful camouflage could be developed for these seasons.

A number of flights were made during the middle of October in order to obtain certain measurements of apparent reflection-factor of earth areas and observations of the hues of the autumn landscape. These observations were not as exhaustive as those recorded in Table I and on other pages, because as has been stated, we are concerned primarily with the summer landscape. The results obtained for the apparent reflection-factors or the brightnesses relative to a perfectly white surface are:

Fields	6.0 per cent.
Barren land	11.3 per cent.
Woods	4.3 per cent.
Inland water	5.5 per cent.

The landscape was decided brownish and generally dull in character. Few green areas were present and the woods displayed a variety of tints. It is noteworthy that the landscape in general appeared more dull and dead from high altitudes than was expected. Although the number of observations was limited to hundreds instead of thousands, as in the investigation conducted during midsummer, it will be noted that the results are not widely different. To obtain low visibility for airplanes viewed from above the brightness would be about the same for late autumn as for summer, but obviously the color would be changed from a very dark olive green to a dark brown or dark greenish-brown. It does not appear practicable to alter the camouflage for airplanes for the autumn season which is relatively short with the possible exception of a relatively few craft. The dark olive green craft would still be of fairly low visibility as viewed from above during the autumn.

7. CLOUDS.

Sunlit clouds are often several times brighter than an adjacent patch of blue sky. This increases the difficulty of realizing low visibility when viewing the airplane from below against the clouds. When the clouds are below the observer they are of course many times brighter than the earth background when they are illuminated by both the sun and the sky. Some measurements were made in the course of these investigations in order to establish the magnitude of the relative brightness or apparent reflection-factor. These values vary considerably with the character of the cloud and the lighting conditions.

The apparent reflection-factor of cumulus clouds receiving full skylight and sunlight as measured vertically above them on various days, varied with the density of the clouds. The mean values of the upper surface of clouds, determined on different days, were found to be as follows:

Very dense clouds (Fig. 9)	0.78
Dense clouds, quite opaque	.62
Dense clouds, quite opaque	.59
Dense clouds, quite opaque	.55
Dense clouds, nearly opaque	.44
Thin clouds	.40
Thin clouds, (Fig. 20)	.36

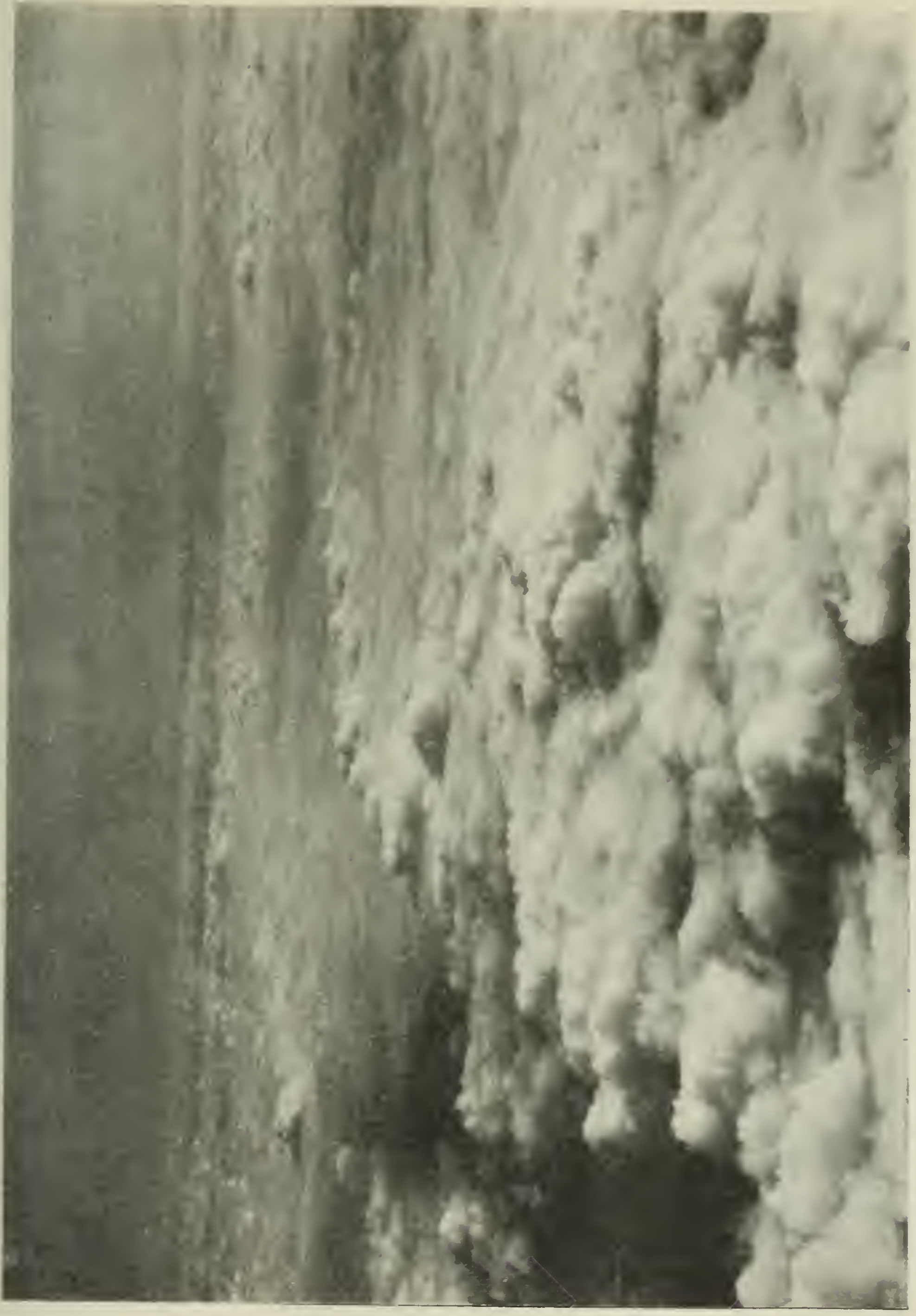
One day when the sky was very heavily overcast, with the exception of a small rift which admitted the airplane with safety to the upper region, a great many measurements of the brightness of the upper surface of the clouds were made. These observations were made near the sunny side of the hole in the extended massive layer of clouds and the values of relative brightness obtained varied from 0.7 to 0.8 with a mean of 0.78. The character of the clouds as seen from above is illustrated in Fig. 9. Inasmuch as the upper side of a cumulus cloud was found to be six times brighter than the lower side, we must conclude that there is a "mass" effect unless we choose to conclude that there is a tremendous absorption. In other words, great masses of clouds can be relatively much brighter than a purely diffusing non-absorbing medium in a thin layer, which theoretically would possess a transmission-factor equal to 0.5 and a reflection-factor of the same value.

The sunlit surfaces of dense clouds were found to be commonly 5 to 10 times the brightness of the adjacent patches of clear blue sky. Ordinary cumulus clouds provide a screen for airplanes as often as they are backgrounds. Cirrus clouds, owing to their great height, are usually backgrounds when they are present. In Fig. 10 a common condition is illustrated. The photograph was taken from an altitude of about 7000 feet, the cumulus clouds being at an altitude of 4500 feet. The effect of the haze is seen by the obscurity of the distant landscape. Some of the other photographs are of interest at this point, especially in showing the high brightness of portions of the clouds and their lack of uniformity in brightness.

8. HAZE.

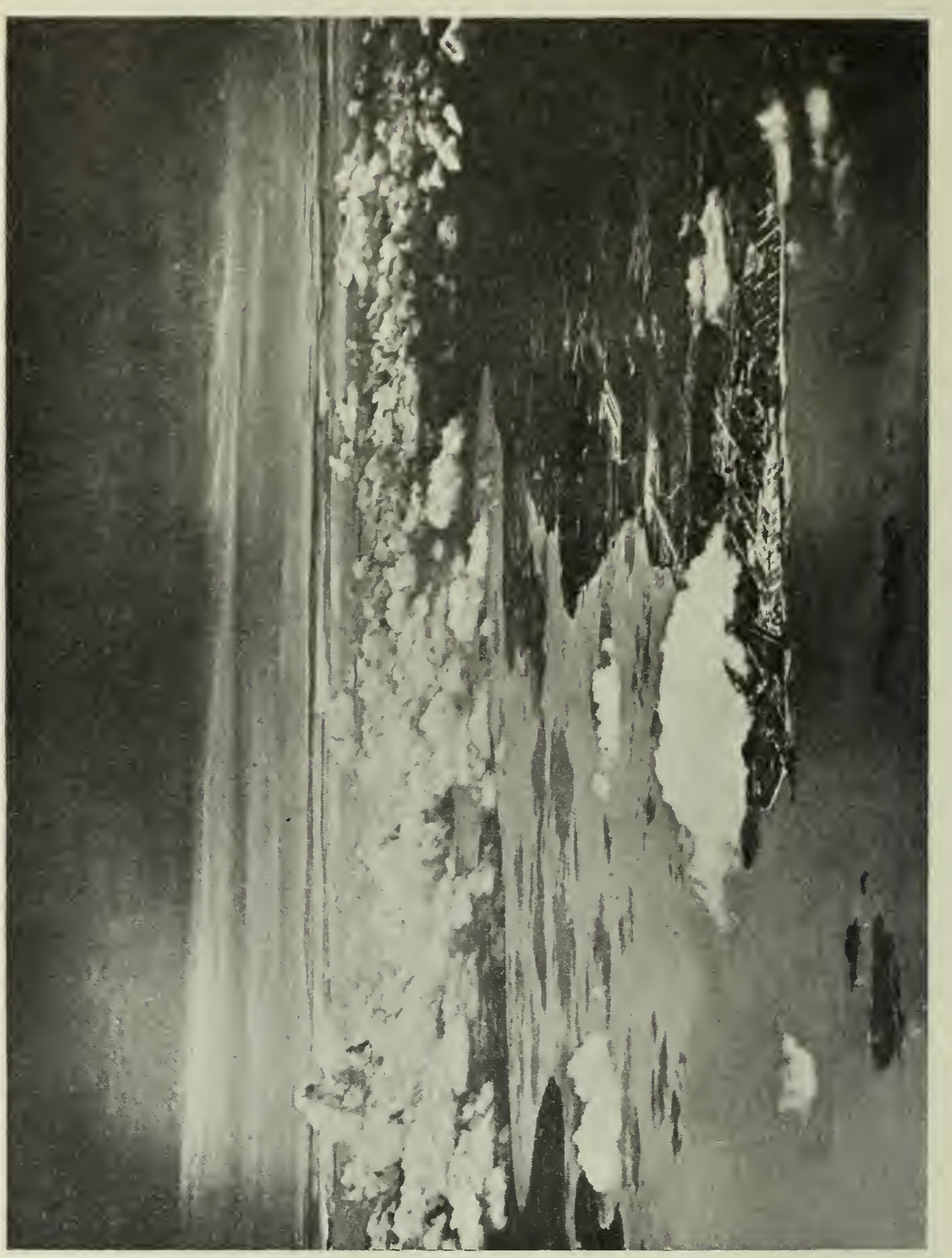
Haze usually tends to lower visibility because it absorbs light reflected from the objects which are viewed and chiefly because

FIG. 9.



Above a dense cloud layer several thousand feet in depth.

Fig. 10.



Illustrating cloud and haze levels also cloud shadows upon water.

it is a luminous veil. In the regions in which these studies were made, the " dust " or low-lying haze extends ordinarily to an altitude of about one mile. This haze is quite absorbing, as is readily seen in viewing the earth obliquely, and also is fairly luminous. On some days the sky, even at altitudes of 10,000 feet, appears quite bright and very unsaturated in color. This upper haze seems to be of the nature of a very thin uniform cloud. Inasmuch as low visibility of airplanes, as viewed from below, for practical reasons is dependent largely upon a dark sky, this upper haze, when it is at such altitudes as to contribute to the brightness of the sky background against which an airplane is viewed, increases the visibility of the craft. The lower or dust haze operates to lower the visibility of craft at moderate and high altitudes.

No very accurate measurements of the luminosity of the low-lying dust haze were obtained, but attempts were made to obtain the order of magnitude. For example, on a cloudless day brightness measurements of water normal to its surface were made at various altitudes from 1000 to 18,000 feet. Although the values for various areas of the water varied slightly, it appeared that the values were about 25 per cent. higher at extremely high altitudes than at the lowest altitudes. This would indicate that, on this particular day, the net result of the haze was to increase the relative brightness of the earth about 25 per cent. On very hazy days this value may be greater.

A better organized attempt was made to determine the change in brightness of the earth with the altitude of observation on a clear day. In order to determine this it is necessary to have a large earth surface of uniform brightness. The brightness of this surface may be determined as viewed from various altitudes. For this purpose a deep channel in the Chesapeake Bay was selected and its brightness was determined for altitudes up to 10,000 feet. No appreciable change was noted, but unfortunately the day was not very hazy. It is doubtful if the change is very much on very hazy days, because the increase in brightness due to the luminous haze as viewed from above is compensated more or less by the decrease in brightness of the earth due to the absorption by the haze of some of the light reflected from it.

No appreciable variation of the total illumination was noted for different altitudes even on very hazy days. On some remarkably clear days, measurements indicated that the sky contributed about 10 per cent. of the total light received at the earth's surface at noon with the sun at about 50 degrees altitude. These results were the lowest ever obtained by the author at the earth's surface.

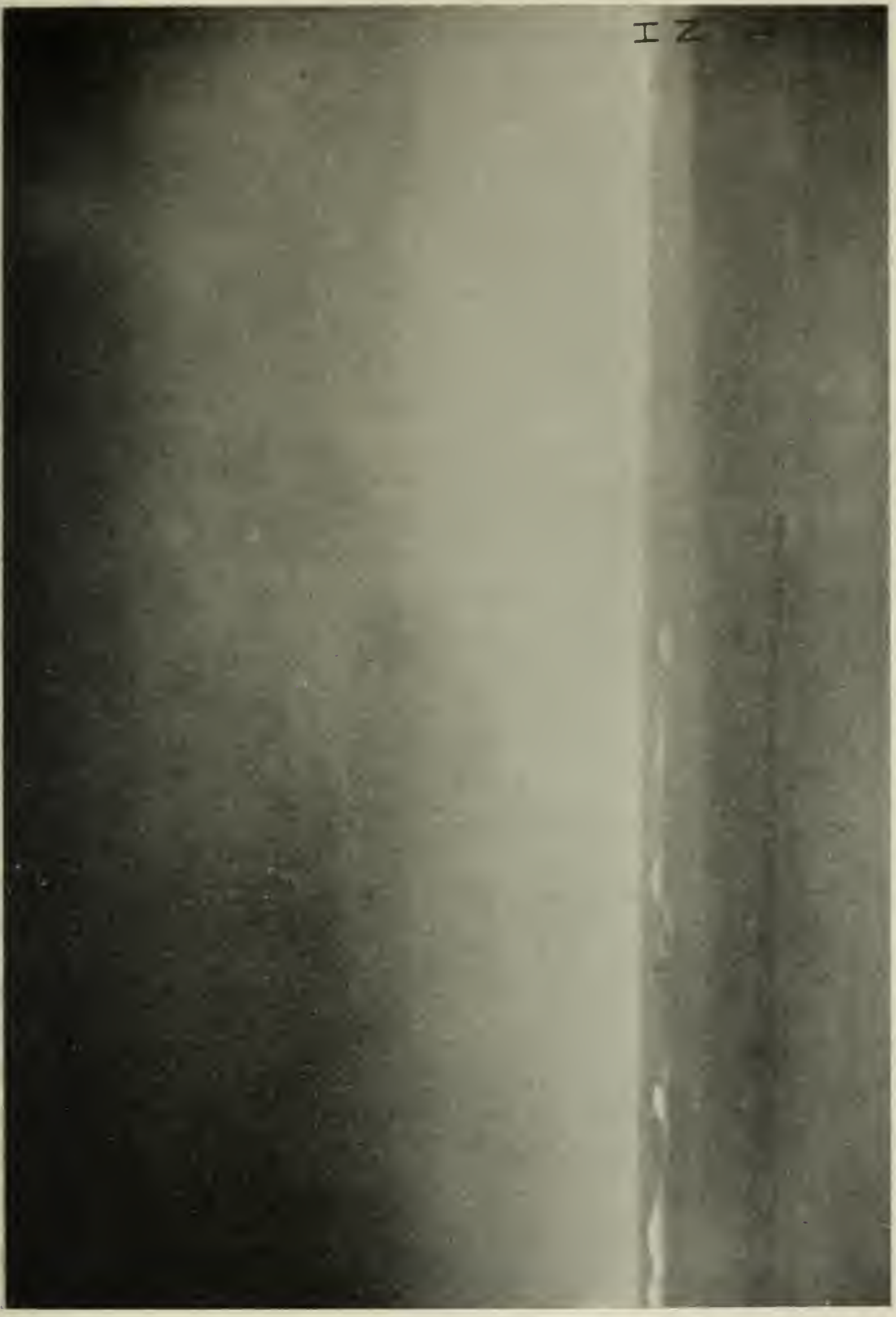
Some measurements of the ratio of upward light to downward light at altitudes of 11,000 feet indicated that about one-tenth as much light was reflected upward as was received downward. Owing to the conditions under which the measurements were made there may be large errors in the results, but they indicate the order of magnitude which checks well with what would be concluded from Table I. Measurements were made of upward light in terms of the sky brightness; that is, of the brightness of a perfectly white horizontal surface illuminated by light reflected upward from the earth, in terms of the brightness of zenith sky. These values were about 1.07 for the particular conditions. Obviously the result depends largely upon the brightness of the sky on a clear day and this varies considerably. The foregoing result was obtained on clear but moderately hazy days. This shows the futility of obtaining low visibility for airplanes, as viewed from below, by merely painting their lower sides white.

The presence and the effect of the earth haze, which ordinarily possesses a fairly definite upper surface at approximately a mile above the earth, are shown in Fig. 11. The "false" horizon due to this dust haze is clearly visible with a few cumulus clouds projecting above it like icebergs. The upper level of this haze is indicated by *H* on the margin of the photograph. The natural horizon *N* is faintly visible below *H*. The remaining portion below *N* is water with the exception of a peninsula of land (Cape Charles), indicated to the left of *L*. Of course, photography cannot accurately reproduce the actual effect of haze on visibility.

9. WATER.

Water forms a part of the background when airplanes are viewed against the ordinary landscape, but it is of little importance individually except as a background for seaplanes. As seen in Table I the mean relative brightness or apparent reflection-factor of inland water, as obtained by measurements perpendicular to its surface, was 0.068. Practically all the values obtained on different days were within the range from 0.05 to 0.1

FIG. 11.



Illustrating haze horizon and cumulus cloud level and most of them were close to the mean value. If the surface of water is perfectly smooth it will reflect at its surface about 0.02 of perpendicularly incident light. This reflection-factor varies only slightly with increasing angle of incidence until about 50 degrees is reached. It begins to increase more rapidly from this angle until obviously at an angle of incidence of 90 degrees it reflects all the light. All values in this paper were obtained by viewing the surface perpendicularly unless otherwise stated.

Owing to the fact that the brightness of an area of water, viewed from above, is due partially to specular reflection, its brightness will depend partially upon the brightness of the objects whose images are reflected. These objects are blue sky, haze, clouds, and the sun; however, the latter will be neglected in this discussion because it is a very special case. It will be seen in Table I that the mean value of the relative brightness of inland water is fairly constant on different days. In fact, this value varies surprisingly little for deep water which would be considered fairly clear. An increased brightness is noted for shallow water and for water which holds fine particles of earth in suspension. For example, measurements on the James River, about 30 miles from its mouth, gave values of 0.10 for shallow water near the shore and 0.075 in mid-stream. The latter value was very constant for its deep channel. Near Richmond where the river was very yellow, due to suspended particles of earth, the relative brightness rose to 0.20, which is very unusual. Many measurements of the brightness of water viewed normal to its surface in terms of the brightness of the zenith sky yielded a mean value of about 0.87. From the position of the observer directly overhead on clear days, the surface reflected only images of portions of blue sky regardless of the character of the waves. It is thus seen that an overwhelming portion of the brightness of the water is due to the light diffused within it. This is obvious in Fig. 10 from the definite shadows on the water cast by the clouds.

(To be concluded.)

ELECTROLYTIC CONDUCTIVITY IN NON-AQUEOUS SOLUTIONS

III. RELATIONS BETWEEN THE CONDUCTIVITY OF THE SOLUTE AND SEVERAL PHYSICAL PROPERTIES OF THE SOLVENT.*

BY

HENRY JERMAIN MAUDE CREIGHTON.
Department of Chemistry, Swarthmore College.
Member of the Institute.

In a previous paper,[1] wherein the relations between the dissociating power of a solvent and its other physcial properties were discussed, it was stated that it had been found that the viscosity of the solvent, the degree of association of the solvent, the associating power of the solvent and the dielectric constant of the solvent are all related to its dissociating power. Some years ago, Walden [2] studied the dissociating power of 49 organic solvents with reference to the same solute, *viz.,* tetraethylammonium iodide. The results of his investigations show that while relations exist between the dissociating power of the solvent and the above-mentioned physical properties, the most important of these relations is that which exists between the dissociating power of the solvent and its dielectric constant. Recently, Creighton and Way[3] studied the conductivity of a solute containing the benzol neucleus, *viz.,* trimethyl-para-tolyl-ammonium iodide, in 13 solvents having different constitutional factors: water, alcohols, aldehydes, ketones, acids, nitriles, nitro-compounds and epichlorhydrin. In the present communication, it is proposed to discuss the data obtained by Creighton and Way with reference to some of the physical properties of the solvents.

The viscosity and the degree of association of solvents have long been recognized as being related to the conductivity of electrolytes. As early as 1856, Wiedermann [4] concluded from his studies of the conductivity of aqueous solutions of copper sulphate that the conductivity of a solution is directly proportional to the concentration and inversely proportional to the viscosity. From a study of the conductivity of various electrolytes in different solvents, Dutoit and Friderich[5] have reached the conclusion that the values for the equivalent conductivity at infinite dilution for a given electrolyte dissolved in different solvents are a direct function of the degree of association of the solvents, and an indirect function of the viscosity of these solvents. This relation, for the most part, was found to hold only qualitatively. Of much more importance is the quantitative relationship established by Jones and his co-workers,[6] which is expressed as follows: the conductivities of comparable equivalent solutions of binary electrolytes in certain solvents (methyl and ethyl alcohols, acetone, etc.) are inversely proportional to the coefficient of viscosity of the solvent in question, and directly proportional to the association factor of the solvent. By comparable equivalent solutions are meant solutions in which the same number of moles of solvent contain the same number of moles of solute. Expressed mathematically, this hypothesis takes the form:

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* Communicated by Professor Creighton.

[1] Creighton, H. J. M., Journ. Franklin Inst., **182**, 745 (1916).

[2] Walden, P., *Zeitschr. phys. Chem.,* **54**, 129 (1905).

[3] Creighton, H. J. M., and Way, D. H., Jour. Franklin Inst., **186** (1918).

[4] Wiedermann, G., *Pogg. Ann.,* **99**, 229 (1856).

$$\frac{\Lambda_v'\eta}{x} = \text{constant},$$

where Λ_v' is the equivalent conductivity of comparable equivalent solutions and η and x are the coefficient of viscosity and the association factor of the solvent respectively. At infinite dilution Jones has shown that

$$\Lambda_\infty \eta = \text{constant};$$

and in an extensive investigation Walden[7] has found that

$$\overset{25}{\Lambda}_\infty \cdot \eta^{25} = 0.7$$

for solutions of tetraethyl- ammonium iodide in thirty solvents.

The foregoing relations have been applied to the conductivity data obtained for solutions of trimethyl-para-tolyl-ammonium iodide in different solvents. The results obtained are given in Table I.

An examination of the values recorded in the last two columns

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[5] Dutoit, P., and Friderich, L., *Bull Soc. Chim.* (3), **19**, 321 (1898).

[6] Jones, H. C., and Co-Workers, *Carnegie Publication*, No. **80** (1907).

[7] Walden, P., *Zeitschr. phys. Chem.*, **55**, 207 (1906).

TABLE I.

Solvent	Coefficient of Viscosity[8] η^{25}	Association Factor[9] x	v'	$\overset{25}{\Lambda}_{v'}$	$\overset{25}{\Lambda}_{\infty}$	$\dfrac{\overset{25}{\Lambda}_{v'}\cdot\eta^{25}}{x}$	$\overset{25}{\Lambda}_{\infty}\cdot\eta^{25}$
Acetone	0.00316	1.26	738	138	188	0.346	0.594
Propylaldehyde	0.00435	1.4	720	95.5	120	0.296	0.414
Propionitrile	0.00413	1.45	887	118.3	143	0.242	0.591
Nitromethane	0.00619	1.88	539	98.4	115	0.324	0.712
Epichlorhydrin	0.0103	1.0	789	38	44	0.391	0.453
Benzaldehyde	0.0140	0.97	1018	26.2	33	0.378	0.462
Formic acid	0.0163[10]	3.61	379	73.2	90	0.331	(1.467)
Anisaldehyde	0.0422	1.31	1217	11	13	0.354	0.464
					Mean:	0.33	
Methyl alcohol	0.00580	3.43	404	84.5	100	0.143	0.580
Ethyl alcohol	0.0112[11]	2.74	586	38.8	48	0.159	0.538
Acetic acid	0.0119[12]	3.62	571	16.5	35	0.054	(0.298)
Benzonitrile	0.0125	0.97	1020	41.8	54	0.539	0.675
Nitrobenzol	0.0182	0.93	1026	31.4	38	0.614	0.692
						Mean:	0.56

of Table I shows that for the first eight solvents the value of $\dfrac{\overset{25}{\Lambda}_{v'}\cdot\eta^{25}}{x}$ is approximately constant; while the values obtained for $\overset{25}{\Lambda}_{\infty}\cdot\eta^{25}$, with the exception of those for acetic and formic acids, lie about a mean value 0.56. When the errors involved in the determination of the quantities employed are taken into consideration, only an approximate constancy could be expected. The values for the degree of association are only approximate, and different observers give different values for the coefficients of viscosity. For solutions of potassium iodide in methyl alcohol and in ethyl alcohol, Jones[13] obtained for $\dfrac{\overset{25}{\Lambda}_{v'}\cdot\eta^{25}}{x}$ the values 0.1408 and 0.1428, respectively. It is worthy of note that these values are not very different from those for trimethyl-para-tolyl-ammonium iodide in the same solvents. The very low value of $\frac{\overset{25}{\Lambda}_{v} \cdot \eta^{25}}{x}$ for acetic acid is interesting, although at present no explanation can be given.

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[8] Except where otherwise noted, the values for the coefficient of viscosity are those determined by Walden, *Zeitschr. phys. Chem.*, **55**, 207 (1906).

[9] The majority of these values have been determined by Ramsay and Shields; the remaining values have been determined by other observers by either Longinescu's method or by Traube's method.

[10] Garner, J. B.; Sexton, B., and Parker, H. O., *Amer. Chem. J.*, **46**, 236 (1911).

[11] Baker, F., *J. Chem. Soc.*, **101**, 1411 (1912).

[12] Kernot, G., and Pomilio, U., Soc. R. Napoli, **17**, 359 (1912).

[13] Jones, H. C., *loc. cit.*, p. 71.

Since $\overset{25}{\Lambda}_{\infty} \cdot \eta^{25}$ has a value of 0.7 for solutions of tetraethyl-ammonium iodide and a value of 0.56 for solutions of trimethyl-para-tolyl-ammonium iodide, it would appear that the value of this constant is dependent upon the nature of the solute.

The conclusions of Dutoit and Friderich [14] and of Dutoit and Aston,[15] that the limiting values of the equivalent conductivity of one and the same solute in different solvents are directly proportional to the degree of association of the latter, and that the conductivity of a solute when dissolved in a non-polymerized solvent is zero, do not hold for solutions of trimethyl-para-tolyl-ammonium iodide in the solvents investigated.

It has been mentioned that of the various relations between the dissociating power of a solvent and its other physical properties, the most important is that which exists between the dielectric constant of the solvent and its dissociating power. According to the Nernst-Thomson hypothesis, that solvent possessing the higher dielectric constant should cause the greater dissociation of the solute at a given dilution. The dissociating power of the solvents under consideration, as expressed by the percentage dissociation of trimethyl-para-tolyl-ammonium iodide at a given dilution, has been calculated for each of the solvents at several dilutions, but only an approximate parallelism has been found to exist between the dissociating power of these solvents and their dielectric constants. This approximate parallelism is shown in Table II, where the percentage dissociation of trimethyl-para-tolyl-ammonium iodide, for dilutions $v = 128$, $v = 1024$ and $v = 2048$, is compared with the magnitude of the dielectric constants of the different solvents.

The values given in Table II for the dissociation of trimethyl-para-tolyl-ammonium iodide show that the magnitude of the dielectric constant is not the sole factor which influences the dissociating power of the solvent. The extent to which the solvent is

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[14] Dutoit, P., and Friderich, L., *loc. cit.*

[15] Dutoit, P., and Aston, E., Compt. rend., **125**, 240 (1897).

TABLE II.

Solvent	Dielectric Constant[16] ϵ	Dissociation of trimethyl-para-tolyl-ammonium iodide at:—		
		$v=128$	$v=1024$	$v=2048$
		Per cent.	*Per cent.*	*Per cent.*
Water	81.7	90	95	96
Formic acid	57.0	73	87	89
Nitromethane	38.2–40.4	78	89	91
Nitrobenzol	33.4–37.4	66	83	87
Methyl alcohol	32.5–34.8	79	90	92
Propionitrile	26.5	67	84	87
Benzonitrile	26.0	54	77	82
Epichlorhydrin	26.0	70	85	88
Ethyl alcohol	21.7–27.4	66	84	87
Acetone	20.7–21.9	54	77	82
Propionaldehyde	14.4–18.5	63	83	86
Benzaldehyde	14.5–16.9	59	79	85
Anisaldehyde	15.5	67	85	88
Acetic acid	6.46	..	72	77

polymerized also plays an important rôle. Thus, at a dilution of $v = 128$, while in methyl alcohol with a dielectric constant of 32.5–34.8 the electrolyte is 79 per cent. dissociated; in nitrobenzol with a slightly higher dielectric constant the electrolyte is only 66 per cent. dissociated. On the other hand, the former solvent is highly associated ($x = 3.43$), while the molecules of the latter are not polymerized at all.

The dissociating power of propionitrile, benzonitrile and epichlorhydrin are particularly interesting, as these solvents have dielectric constants of approximately the same magnitude. That polymerization plays a part, however, is suggested by the fact that while the molecules of propionitrile are associated to a considerable extent, those of benzonitrile do not associate. This behavior is in agreement with the results of Schlundt,[17] who found that the conductivities of silver nitrate in these two dielectrically equal solvents gave differences in the sense that the conductivity in benzonitrile corresponds to a smaller ionic concentration. On the other hand, the dissociating power of epichlorhydrin is considerably greater than that of benzonitrile, although the dielectric constants and the degrees of association of these two solvents are approximately the same.

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[16] Drude, P., *Zeitschr. phys. Chem.*, 23, 308 (1897); Schlundt, H., *Jour. Phys. Chem.*, 5, 165 (1901); Mathews, J. H., *ibid*, 9, 667 (1905).

[17] Schlundt, H., *loc. cit.*

The dissociation of trimethyl-para-tolyl-ammonium iodide in formic acid is very much smaller than would be expected in view of the high degree of association and the large dielectric constant of this solvent. This may possibly be due to the fact that in formic acid the molecules of many substances associate to polymerized molecules, and in consequence, therefore, the relatively small dissociation of trimethyl-para-tolyl-ammonium iodide may result from the reduction in the number of molecules effected by association being greater than the increase which has its origin in ionization. It may be assumed, in accordance with the equilibrium laws, that a decrease in ionization must result from a large reduction of the active mass of the simple molecules through polymerization, since it is only the simple molecules which are capable of producing ions.

SUMMARY AND CONCLUSIONS.

1. The results of measurements of the conductivity of trimethyl-para-tolyl-ammonium iodide in thirteen solvents have been discussed with reference to the viscosity, the degree of association and the dielectric constant of the solvents.

2. It has been found that the relation established by Jones between the conductivity of the solute, and the viscosity and the degree of association of the solvent holds in a general way for the solvents considered. The Nernst-Thomson hypothesis has been found to hold only approximately.

3. While the relations considered are by no means quantitative, it must be remembered that the data are subject to much uncertainty. The values for Λ_{∞}^{25} have been obtained either by calculation or by graphic extrapolation, and consequently the values for the degree of dissociation of the solute are only approximate. The magnitudes for the degree of association and the dielectric constant of the solvents are also more or less uncertain, and do not in many cases refer to the temperature at which the conductivity measurements were carried out. Further, the relations considered are probably complicated by the association of the molecules of the solute to form polymerized molecules.

Department of Chemistry,
Swarthmore College,
Swarthmore, Pa.,
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INVESTIGATIONS ON THE ABSORPTION OF WATER BY GELATINE.*

BY

EDITH B. SHREVE,
Desert Laboratory, Tucson, Arizona.

During the last few years we have been almost deluged with extremely interesting theories of physiological behavior which have been drawn from the field of colloidal chemistry. However, the science of colloidal chemistry is still so much in its infancy that it behooves us to desist from making applications for a time, and to take measures to verify our facts. The imbibition of water, and of solutions, by jellies has proved the most fruitful source for speculation, and yet an examination of the literature on this subject shows much contradiction in the results of experimental work. Consequently, it seems very important that more physiologists give time to the accurate study of the imbibitional properties of jellies. This paper contains the facts obtained from work on some of the imbibitional phenomena of gelatine jelly. The results are offered at this time without their theoretical significance in the hope that they may aid other workers in their effort to obtain the facts of imbibition in comparable form; and also that a warning note may be sounded against too readily forming conclusions concerning physiological behavior from work with gelatine or other colloidal jellies before the behavior of the gelatine itself is ascertained.

METHODS.

A former paper[1] described the precautions which I have found necessary to take in order to obtain gelatine jelly that will always show the same imbibitional behavior when treated in the same way. The various methods for the measurement of the uptake of water by gelatine must be considered carefully before an investigation into the influence of various materials, of temperature, or of any other factor upon the absorbing capacity can be undertaken. Two general methods for measurement of the amount of water imbibed present themselves, namely: (1) increase in weight, and (2) increase in volume.

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* Communicated by the Author.

[1] "Investigations on the Imbibition of Water by Gelatine." Shreve, E. B. *Science:* N. S., vol. xlviii, No. 1239.

Tables I and II give some of the results obtained when measurements of weight and volume were made on the same material. From these and other experiments, it is evident that the ratio of increase in weight to increase in volume is a constant. The increase in volume was measured by the displacement of the liquid which the disks were absorbing. A burette graduated to 0.1 c.c. was used for the readings. When this method of volume measurement was used there was a greater variation between duplicates than when the weighing method was used. Other experiments in which volume was calculated from direct measurement of individual pieces were much less satisfactory. The reason for this is two-fold: first, the time involved in the measure-

TABLE I.

Comparison of the Number of Grams gain in Weight with the Number of Cubic Centimeters Gain in Volume for Small Disks of Gelatine Jelly. Gelatin = 33 per cent., Distilled Water = 67 per cent. Disks Were Placed in Distilled Water. Each Number Represents the Total Gain for 30 Disks for the Time Indicated.

Method of measurement	Lot 1	Lot 2	Lot 3	Lot 4	Lot 5	Lot 6	Time
Weight......	2.68	2.58	2.60	2.60	2.65	2.68	24 hrs.
Volume.....	3.0	4.0	3.5	2.9	2.6	2.8	24 hrs.
Weight......	5.2	5.2	4.89	4.83	5.28	5.24	48 hrs.
Volume.....	6.1	5.5	5.8	5.4	5.3	4.7	48 hrs.

TABLE II.

Comparison of Gain in Weight with Gain in Volume of Disks of Gelatine Jelly. Both Sets of Readings Reduced to Gain per Hour per Gram of Dry Weight of Gelatine. Gain in Volume Measured by Displacement. Lot No. 1 = 33 per cent. Gelatine and 67 per cent. Distilled Water. Lot No. 2 = 33 per cent. Gelatine and 67 per cent. M Sodium Sulphate. Lot No. 3 = 33 per cent. Gelatine and 67 per cent. M/2 Sodium Sulphate. Thirty Disks of Same Size in Each Lot. All Placed in Distilled Water.

Method of measurement	Lot 1		Lot 2		Lot 3		Time
	A	*B*	*A*	*B*	*A*	*B*	
Weight.............	0.65	0.64	2.08	1.98	0.93	0.93	2 hrs.
Volume............	0.68	0.73	2.20	1.90	0.96	0.85	2 hrs.

ments is too great to allow enough pieces to be measured to insure a good average, and, second, the error in measuring the pieces after they have become slightly soft is very great.

It has frequently been the custom to measure the increase of one dimension instead of the entire volume. In a former article [2] I have given the precautions for the use of this method, when gelatine which has lost water by evaporation is used. The ratios given in Table III bring out the relation between gain in height and gain in weight. Increase in height was measured by the MacDougal auxograph.[3] Three disks were placed under the glass triangle of each of twelve instruments and the results were averaged.

TABLE III.

Comparison of Increase in Height with Increase in Weight. Disks of 10 per cent. Gelatine Jelly Which Has Not Lost Water by Evaporation Were Placed in Distilled Water (Lot 1), in M/200 Hydrochloric Acid (Lot 2), and in M/50 Sodium Hydroxide (Lot 3). Increase in Height was Measured by Auxograph. Height Readings are Reduced to Number of Centimeters per 100 Centimeters of Original Thickness and Weight Readings to Grams per 100 Grams of Original Weight. Each Number is an Average of Readings Taken on Twenty-four Pieces of Jelly. Ratios Appear in Parentheses Beneath Numbers.

Method of measurement	Lot 1	Lot 2	Lot 3
Weight	21.8 (1.0)	12.1 (0.55)	91.2 (4.18)
Height	4.8 (1.0)	3.6 (0.75)	19.5 (4.06)

An idea of the variation between different readings to be expected with the auxograph and with the micrometer calipers may be had from Table IV. The probable variation to be found when the weighing method is used may be seen from many later tables in the paper.

It seems evident that so long as large differences are involved, it makes little difference what method is employed, just so the same one is used for all measurements. However, when the detection of smaller differences becomes desirable, it is then advisable to consider the range of probable variations and the precautions necessary in the use of the several methods. It must be borne in mind, too, that the variations may not always be traceable to experimental error, but may be due to the nature of the material.

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[2] Shreve, E. B., *loc. cit.*

[3] MacDougal, D. T., and Spoehr, H. A., "Growth and Imbibition." Proc. Amer. Phil. Soc., lvi, No. 4, 1917, p. 329.

The results obtained from the measurement of increase in weight show less variation between duplicates than from any of the other methods. This is due to two causes: the first, and most important, being the possibility of using a much larger quantity of material for one reading, and, second, the lower experimental error found in the balances. A convenient unit for measurement is gain in weight per gram of oven-dried gelatine present. In all cases where results are needed no more frequently than once in two hours I have found that the weighing method is most satisfactory.

TABLE IV.

Number of Centimeters Increase per Centimeter of Original Height (Axis of greatest Evaporation) in Rectangles of Air Dry Gelatine (Originally 15 per cent.) When Allowed to Absorb Water for Sixteen Hours. Comparison of Measurements by Micrometer Calipers, with Readings for Auxograph Traces. Original Thickness Measured with Calipers in Both Cases. Each Number is an Average of Measurements on Three blocks.

Instrument										
Auxograph......	7.50	6.20	6.20	6.20	6.20	5.20	5.55	6.90	6.50	8.70
Micrometer calipers..........	8.10	7.00	8.70	7.80	7.60	5.20	5.10	8.60	7.10	8.20

The measurement by hand, of increase in size, is out of the question for reasons mentioned in an earlier paragraph and, furthermore, it has no advantage over the weighing method. The measurement of increase in size by means of the auxograph has distinct advantages in some kinds of work as it gives an automatic record of swelling with time, and in some experiments it is highly desirable to have a continuous record for the first few hours. However, as the gelatine becomes softer with its increasing water-content, the measurement by auxograph becomes more difficult, the weighing method showing an increase in water-content many hours after the auxograph has ceased to show an increase in thickness. Another drawback to the auxograph for most work is the number of instruments required to obtain enough readings to get a reliable average. Only three pieces can be used conveniently under one instrument. However, if a constant temperature room is available many readings may be taken consecutively on the same instrument. The experiments reported upon in the following pages are of such a nature that readings taken every two hours were frequent enough, and consequently the weighing method was used.

Increase in thickness (*i.e.,* along the axis of greatest evaporation) was found to be proportional to increase in volume, but increase in either of the other dimensions was not necessarily so. Thus, when an experiment was made, to discover the influence of size on the water-absorbing rate of certain blocks of gelatine, measurements of thickness, of volume, and of increase in weight showed a slower rate for large than for small pieces; but no such relation could be detected by measurements of breadth. In this case, volume was determined from measurements of thickness and area.

Whatever method is used for the measurement of imbibition, it is necessary, of course, to use pieces of the same size and form when comparisons are made. However, certain small differences in size which occur, because of unavoidable experimental errors, need not be taken into account. It is essential, though, to determine the error that may be neglected in each particular case. For example, it was found that the error is negligible if disks larger than 0.5 cm. in diameter are cut with the same glass rod, or if cylindrical moulds 1 cm. in diameter have a variation of 5 per cent. in diameter.

The same general methods were used in all of the experiments which follow. The jellies used for the absorption tests were made thus: Leaves of "Silver Brand" gelatine were selected of even thickness, the thick edges trimmed off with scissors and the remaining part cut into small squares. These squares were then placed in a large desiccator and dried to constant weight at 40° C., 20 grams were then weighed out, mixed with 50 c.c. of water or of a solution of the desired strength and allowed to stand for three hours. The gelatine with its accompanying liquid was then heated over a water-bath (50°–60° C.) until the gelatine was completely melted. The resulting liquid was well mixed with a glass rod. In those experiments that are marked "disks" the gelatine was then immediately poured into stender dishes of about 12 inches in diameter. These dishes were placed on a small leveling table inside of a refrigerator and left there until the lot had "set", when disks 2 cm. in diameter were cut with a glass tube having a ground glass edge. The disks were always handled with a gold-tipped forceps and a gold lifter. In some cases these disks were used immediately, and in others they were allowed to lose water by evaporation before they were tested for imbibition. In both of these cases the imbibition tests proceeded in the same manner. The disks were first weighed in covered weighing bottles (7 cm. in diameter) and then transferred to large flat crystallizing dishes and the desired liquids poured over them. The disks were always placed far enough apart to prevent their touching after swelling. At the close of the chosen interval of time the disks were carefully lifted from the solution and transferred to filter paper. They were gently blotted with another piece of filter paper until all free water was removed. The disks were weighed in the bottles and afterwards returned to their solutions. Thirty disks were used for each test. This method gave satisfactory results, but on account of the time involved in handling the disks, it was replaced later by another method in all experiments where the jellies were not evaporated to dryness. This later method was used in those experiments marked " dishes." It was identical with the one just described up to the point where the gelatine was ready to be poured out for the setting. In this case 10 c.c., and later 5 c.c., of the liquid gelatine was drawn off in a pipette and allowed to flow into small cylindrical glass dishes about 6 cm. in diameter and 3 cm. high. These dishes had vertical sides, accurately made flat bottoms and possessed glass covers ground to fit. The dishes were placed on a levelling table in a refrigerator until the gelatine had set. After the dishes with their gelatine had been weighed, a measured amount of water or of the desired solution was poured over the top of the gelatine, the covers replaced and the dishes placed in a refrigerator. At the end of the chosen interval of time the liquid was poured into another dish, the surface of the gelatine carefully dried with filter paper, the cover replaced and the dish weighed. After each weighing, the same liquid was returned to the gelatine. A reference to the tables will show that duplicates by this method gave a very small amount of variation. The numbers (1 and 2) at the heads of the column in the experiments marked " dishes " refer each to readings from one dish.

It will be noted that the amounts are always reduced to grams per gram of dry weight of gelatine. It may be said first of all that the same ratios hold whether the unit of measurement was a given number of disks, a dish of gelatine of the size and kind referred to above or the unit that appears in the tables. The methods for determining the amount of dry weight of gelatine, of course, varied according to the salts included. The final dry weight of the mixture could naturally not be taken because of the passage of salts into and out of the gelatine. In all cases chemical analysis was resorted to, but since the reduction of the results to grams per gram of dry weight of gelatine never changed the ratio values enough to make any difference in the conclusions, the details of the chemical analysis will be omitted. The analyses were undertaken to find any possible difference in the ratios that might exist. A solution of 50 c.c. does not contain exactly 50 c.c. of water; consequently, in order to insure a constant water-content for all the samples, a small correction was made when necessary in the amount of solution added, so that all water-contents might be the same at the start. The entire water and evaporation history of every sample was identical from beginning to end of the experiment.

EFFECT OF HEAT ON THE IMBIBITION OF WATER BY GELATINE.

Some confusion exists in the literature over several points which have to do with facts which are necessary to discussions of theory. For example, Taylor,[4] interpreting Hofmeister, says of elastic jellies: "The quantity of liquid which can be taken up reaches a maximum, which depends on the gel, on the liquid, on the temperature and on the viscosity of the liquid. There is always contraction and always evolution of heat, from which, according to le Chatelier's theorem, heat will hinder or diminish imbibition, while cold and pressure will favor it." On the other hand, Fischer,[5] in his work with gelatine, attributes the "marked absolute difference in the amount of swelling" between various experiments to the difference in temperature which existed when all other conditions were identical, the gelatine which showed the greatest swelling being at the highest temperature. MacDougal,[6] working with a mixture of agar, bean protein and nutrient salts, draws from the results of his experiments the following conclusion: "The swelling of biocolloids is seen to increase in initial velocity and total amount to a maximum between 39° C. and 46° C. in the salted mixture and to 46° C. in the unsalted."

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[4] Taylor, W. W., "The Chemistry of Colloids." New York, 1915, p. 155.

[5] Fischer, Martin H., "Œdema." New York, 1910.

[6] MacDougal, D. T., Proc. Soc. Exp. Biol. and Med., xv, 48–51. 1917.

I have measured the rate of imbibition of water by gelatine at three different temperatures and have endeavored to find the[7] maximum water-content of the gelatine at the various temperatures. In trials of five hundred pieces, which included various sizes and thickness, and gelatine in various initial conditions of water-content, I found that, without a single exception, the higher the temperature (of course, within the limits where gelatine exists as a jelly) the greater the rate of imbibition and the greater the maximum at the point of apparent equilibrium. Table XVI presents a fair sample of the results which were obtained. Furthermore, when the temperature of imbibing gelatine was raised, its rate was always increased.

The statement above quoted from Taylor does not, then, stand the test of experiment. There may be more than one reason why this is so.

Le Chatelier's theorem may be stated briefly as follows:[8] "If we heat a chemical system, at constant volume, then there occurs a displacement of the state of equilibrium, and in that direction toward which the reaction advances with absorption of heat. If we compress a chemical system at constant temperature, there follows a displacement of the equilibrium in that direction which is associated with a diminution of volume."

Measurements have been made by so many workers that there can be no doubt about the fact that the uptake of water by gelatine is accompanied by evolution of heat and decrease of total volume (water plus gelatine).

If we decide to take it for granted that the mixture, water plus gelatine jelly, constitutes a "chemical system," then the first obvious thing to determine is whether or not we are dealing with an equilibrium phenomenon. To quote again from Nernst[9]: "Moreover, it requires great precaution before one can regard a system as actually having arrived at a state of equilibrium. For the observation that no material change can be observed, even after a lapse of quite a long time, is by no means always sufficient."

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[7] The value of this as an approximation is discussed later.

[8] Nernst, W., "Theoretical Chemistry." Trans. by Palmer. New York, 1895.

[9] Nernst, *loc. cit.*, p. 356.

In regard to this same subject, Washburn[10] says: "False equilibria are sometimes met with, due to various causes, such as * * * slow diffusion of one or more of the substances involved * * * In order to make sure the equilibrium should be approached from both directions."

In my experiments, apparent equilibria were attained at various temperatures, that is, the gelatine jelly ceased to gain in weight a measurable amount in forty-eight hours, in the presence of water. Whenever the temperature of such an apparent equilibrium was raised, the gelatine took up more water, but a lowering of the temperature caused neither a loss nor a gain of water. Consequently, the supposed equilibrium cannot be approached from "both directions."

Furthermore, it is a well-known fact that[11] "* * * all experimental measurement has shown that the velocity with which a chemical system strives to reach its state of equilibrium increases enormously with the temperature." Now in my experiments a rise of temperature always caused a marked increase in the rate of water uptake and a lowering of temperature a corresponding decrease in rate. This, when considered in the light of the known heat relations of imbibition and le Chatelier's theorem, is another bit of evidence that equilibria observed at the respective temperatures are only apparent ones.

Two important facts have a bearing upon this matter, the one that the diffusion of water through gelatine jelly is known to be relatively slow and the other that rate of diffusion always increases with temperature. After obtaining the apparent equilibrium point with thin pieces of gelatine, I have numerous times cut the pieces into smaller fragments and obtained an increase within a few hours, showing that diffusion of water into the interior had not been completed. It is impossible to continue any given experiment for more than two weeks above 25° C., or four weeks at 10°–20° C., because of bacterial infection. The difficulty of sterilizing the gelatine itself without changing its constitution by heat or altering its tendency to absorb water by the addition of a sterilizing agent seems unsurmountable at present. Consequently, it is not now possible to make tests to show whether or not any given sizable piece of gelatine will become completely dispersed in water at temperatures below 25° C., but it is evident that some of the gelatine passes from the surfaces and becomes dispersed in the water. A very appreciable amount of gelatine is always obtained when the water which has surrounded pieces of gelatine for any length of time is evaporated to dryness.

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[10] Washburn, E. W., "Principles of Physical Chemistry." New York, 1915, p. 279.

[11] Nernst, *loc. cit.*, p. 568.

So the evidence all goes to show that gelatine takes up water to at least nearly unlimited amounts at temperatures from 10° to 30° C. when given unlimited time—that there is no temperature below the point of liquefaction of gelatine where a true point of equilibrium is reached within less than two weeks. Thus the fact that heat favors imbibition in gelatine offers no contradiction to the laws of thermodynamics. Indeed, considering the firm basis on which thermodynamic laws are founded, it would seem more logical to argue in the opposite direction from the experimental data, and to say that since heat favors imbibition in an exothermic reaction, then there is no true point of equilibrium measured within the range of temperatures used. Of course, as soon as the jelly begins to assume the liquid state then the action becomes endothermic, and here we are introduced to the riddle of another equilibrium point.

So far as biological phenomena and their interpretation are concerned, the apparent equilibria may usually be treated as real ones, because all important biological phenomena take place within a limited time; it is only when we try to make predictions from theoretical reasoning that caution must be observed.

EFFECT EXERTED ON THE IMBIBITION OF WATER, OF INCLUDING VARIOUS SOLUTIONS WITHIN GELATINE JELLY.

Ever since the time of Hofmeister, it has been known that the imbibition of gelatine can be greatly changed by the addition of acids, bases or salts to the water which is being imbibed, and many theories have been advanced based on Hofmeister's series. For example, Taylor says: "Arranged in order of increasing effectiveness in promoting imbibition, the series is sodium-sulphate, tartrate, citrate, acetate; alcohol, glucose, cane sugar; (water) chlorides-potassium, sodium, ammounium, sodium chlorate, nitrate, bromide; * * * The substances before water hinder imbibition * * * while the salts after favor imbibition. The order is again the lyotrope series which we have come across so often. As already seen, the modulus of elasticity is affected by salts in the lyotrope order; this is the same series in the reverse order. As was to be expected, a substance which renders a gel more easily deformed (reduction of E) will favor imbibition."

Now this reasoning is based on the assumption that the salts affect the gelatine by their presence in it. Since the salts quickly become disseminated through the gelatine by the processes of diffusion and adsorption, it seems reasonable to suppose that the same effect might be had if the salts are made up into the gelatine and the mixture allowed to absorb water. Indeed, it must be so unless such reasoning as that given above is to be modified. I have undertaken a series of experiments to test this matter and the results have been most unexpected.

Tables V–XIII show that if the salts belonging to the class which increase imbibition are made up in solution in the gelatine and the resulting jelly allowed to absorb water, the imbibition is also increased; and that when salts which belong to the class that decrease imbibition are made up in the gelatine and this resulting jelly allowed to absorb water that imbibition is increased. All the salts tried in the experiments increase the imbibition of water if they are made up in the gelatine itself.

TABLE V.

Imbibition per Hour per Gram of Dry Gelatine of: (A) 28 per cent. Gelatine Plus 72 per cent. Water, Placed in Water; (B) 28 per cent. Gelatine Plus 72 per cent. M Ammonium Chloride, Placed in Water. Jellies not Allowed to lose Water After Being Made up. Ratios Calculated from Averages Appear in Parentheses Below Numbers.

Time	*A*		*B*	
	1	2	1	2
1st to 4th hr.	0.918	0.923	1.470	1.474
	(1.00)		(1.60)	
4th to 7th hr.	0.332	0.334	0.515	0.512
	(1.00)		(1.54)	
7th to 12th hr.	0.059	0.065	0.105	0.110
	(1.00)		(1.74)	

Now it will be noted that when these substances were made up in the gelatine that the mixture stood at 50°–60° C. over a water-bath for about 15 minutes. Consequently, it is possible that a chemical change occurred between gelatine and salt which might not have taken place if the substances had been inserted into the gelatine at a lower temperature. Therefore, it seemed

TABLE VI.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Chloride, Imbibing Water; (C) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Chloride, Imbibing Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from Averages of the Duplicates Appear in Brackets Beneath the Numbers. Disks.

Time	*B*		*B*		*C*	
	1	2	1	2	1	2
1st to 3rd hr..........	0.742	0.746	1.161	1.153	1.229	1.239
	(1.0)		(1.6)		(1.7)	
3rd to 6th hr.........	0.755	0.760	0.850	0.852	1.345	1.350
	(1.0)		(1.1)		(1.8)	
6th to 18th hr........	0.225	0.235	0.261	0.273	0.453	0.453
	(1.0)		(1.2)		(2.0)	
18th to 42nd hr.......	0.044		0.045	0.057	0.124	
	(1.0)		(1.2)		(2.8)	

TABLE VII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Placed in Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Placed in M Cane Sugar; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Placed in M/2 Cane Sugar; (D) 28 per cent. Gelatine Made up With 72 per cent. M Cane Sugar, Placed in Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M/2 Cane Sugar, Placed in Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below Numbers. Disks.

Time	*A*		*B*		*C*		*D*		*E*	
	1	2	1	2	1	2	1	2	1	2
1st to 2nd hr.	0.256	0.248	−0.041	−*0.037	0.113	0.113	0.291	0.388	0.314	0.314
2nd to 3rd hr.	0.121	0.127	−0.014	−0.014	0.073	0.075	0.200	0.194	0.153	0.151
3rd to 4th hr.	0.076	0.080	−0.012	−0.012	0.034	0.042	0.145	0.145	0.118	0.125

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* Negative sign indicates decrease in weight.

advisable to make up the gelatine in the usual proportions (20 of gelatine to 50 of water), allow it to set and then to absorb all of a small quantity of a solution of the substance whose presence is desired in the gelatine jelly. The gelatine was made up as has been described on page 324, 10 c.c. of liquid gelatine being transferred to each small dish by means of a pipette, all of the

TABLE VIII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing 2M Ethyl Alcohol; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M Ethyl Alcohol; (D) 28 per cent. Gelatine Made up With 72 per cent. 2M Ethyl Alcohol, Imbibing Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M Ethyl Alcohol, Imbibing Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of Duplicates Appear in Brackets Below Numbers. Disks.

Time	*A*		*B*		*C*		*D*		*E*	
	1	2	1	2	1	2	1	2	1	2
1st to 2d hr.	0.247	0.248	0.097.	0.097	0.171	0.173	0.344	0.347	0.284	0.289
	(1.00)		(0.39)		(0.69)		(1.39)		(1.16)	
2nd to 3rd hr.....	0.128	0.131	0.054	0.051	0.072	0.072	0.155	0.155	0.151	0.150
	(1.00)		(0.41)		(0.055)		(1.19)		(1.06)	
3rd to 4th hr.....	0.082	0.088	0.043	0.046	0.062	0.066	0.097	0.105	0.088	0.091
	(1.00)		(0.53)		(0.75)		(1.19)		(1.06)	

TABLE IX.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing 2M Sodium Citrate; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M Sodium Citrate; (D) 28 per cent. Gelatine Made up With 72 per cent. 2M Sodium Citrate, Imbibing Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Citrate, Imbibing Water. Jellies not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below the Numbers. Dishes.

Time	*A*		*B*		*C*		*D*		*E*	
	1	2	1	2	1	2	1	2	1	
1st to 2nd hr.	0.200	0.206	0.032	0.031	0.132	0.134	0.349	0.355	0.287	0.289
	(1.00)		(0.16)		(0.65)		(1.73)		(1.42)	
2nd to 3rd hr.	0.111	0.117	0.030	0.035	0.075	0.078	0.209	0.200	0.191	0.181
	(1.00)		(0.29)		(0.66)		(1.80)		(1.63)	
3rd to 4th hr.	0.091	0.097	0.036	0.045	0.078	0.082	0.170	0.176	0.165	0.170
	(1.00)		(0.43)		(0.85)		(1.84)		(1.79)	

TABLE X.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing 2M Sodium Tartrate; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M Sodium Tartrate; (D) 28 per cent. Gelatine Made up With 72 per cent. 2M Sodium Tartrate, Imbibing Water; (E) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Tartrate, Imbibing Water. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from Averages of the Duplicates Appear in Brackets Under the Numbers. Dishes.

Time	*A*		*B*		*C*		*D*		*E*	
	1	2	1	2	1	2	1	2	1	2
2 hrs.	0.548	0.569	0.356	0.361	0.475	0.481	0.735	0.739	0.654	0.664
	(1.00)		(0.64)		(0.96)		(1.33)		(1.18)	

TABLE XI.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M/2 Sodium Sulphate, Imbibing Water; (C) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M/2 Sodium Sulphate. Jellies Allowed to Lose Water Until Constant Weight at Air Temperature was Reached Before Imbibition Began. Ratios Calculated from Averages of Duplicates Appear Beneath Numbers. Disks.

Time	*A*		*B*		*C*	
	1	2	1	2	1	2
3 hrs.	0.572	0.563	0.903	0.911	0.432	0.450
	(1.00)		(1.60)		(0.8)	

TABLE XII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M Sodium Sulphate, Imbibing Water; (C) 28 per cent. Gelatine Made up With M/2 Sodium Sulphate, Imbibing Water; Jellies Allowed to Lose Water Until Constant Weight at Air Temperature was Reached Before They were Placed in Water. Ratios Calculated from Averages of Duplicates Appear in Brackets Beneath Numbers. Disks.

Time	*A*		*B*		*C*	
	1	2	1	2	1	2
2 hrs.	0.641	0.649	0.207	0.199	0.926	0.934
	(1.0)		(3.1)		(1.4)	

gelatine allowed to set and then 3 c.c. of the appropriate solution placed over the surface. The dishes were tightly covered and allowed to stand at about 12° C. for twenty-four hours, at the end of which time all of the solutions had been absorbed by the gelatine. The disks were then removed from the dishes and allowed to lose water until constant weight was attained at air temperature. Drying was hastened by means of an electric fan. After all the disks had attained equal water-content, they were placed in dishes of distilled water, from which they were removed at stated intervals, dried and weighed for the increase in weight.

TABLE XIII.

Imbibition per Hour per Gram of Dry Gelatine of Jellies of the Following Compositions: (A) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing Water; (B) 28 per cent. Gelatine Made up With 72 per cent. M/2 Sodium Sulphate, Imbibing Water; (C) 28 per cent. Gelatine Made up With 72 per cent. M/5 Sodium Sulphate, Imbibing Water; (D) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M/2 Sodium Sulphate; (E) 28 per cent. Gelatine Made up With 72 per cent. Water, Imbibing M/5 Sodium Sulphate. Jellies Not Allowed to Lose Water After Being Made up. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below the Numbers. Dishes.

Hours	*A*		*B*		*C*		*D*		*E*	
	1	2	1	2	1	2	1	2	1	2
8 hrs.	0.526	0.522	0.885	0.878	0.851	0.859	0.374	0.382	0.515	0.530
	(1.0)		(1.7)		(1.6)		(0.7)		(1.0)	

TABLE XIV.

Imbibition per Hour per Gram of Dry Weight of Gelatine from Gelatine Disks (28 per cent. Gelatine to 72 per cent. Water) which have Absorbed in the Cold Equal Volumes of the Following: (A) Distilled Water; (B) Molecular, Sodium Bromide; (C) Molecular, Ammonium Chloride; (D) Molecular, Sugar; (E) One-half Molecular, Sodium Citrate; (F) One-half Molecular, Sodium Sulphate, all Imbibing Water. Disks were Air Dry at Beginning of Experiment. Ratios Calculated from the Averages of the Duplicates Appear in Brackets Below Numbers.

Hours	*A*		*B*		*C*		*D*		*E*		*F*	
	1	2	1	2	1	2	1	2	1	2	1	2
0–2.	0.713	0.718	0.900	0.906	0.799	0.815	0.663	0.631	0.973	0.949	0.930	0.922
	(1.00)		(1.26)		(1.13)		(0.90)		(1.34)		(1.29)	
2–4.	0.306	0.298	0.372	0.372	0.319	0.309	0.416	0.390	0.579	0.569	0.410	0.414
	(1.00)		(1.23)		(1.04)		(1.33)		(1.90)		(1.36)	
4–23. . . .	0.113	0.110	0.115	0.119	0.115	0.115	0.089	0.111	0.123	0.129	0.104	0.111
	(1.00)		(1.05)		(1.04)		(0.901)		(1.13)		(0.96)	

Table XIV shows an increase in imbibitional rate for the first four hours in the case of all the substances used, with the exception of cane sugar, which is irregular in its behavior. Sodium citrate and sodium sulphate, substances which decrease the imbibition of gelatine when in the external solution, cause the greatest increase in rate here. For the next nineteen hours the rates became nearly equal for all the substances. Subsequent evaporation of the various liquids surrounding the gelatine showed that much of the material that had been included in the gelatine diffused out into the surrounding water and so later results could not be expected to agree with the earlier ones.

Table XV gives the results obtained from a similar experiment when the gelatine used for imbibition was not allowed to lose water by evaporation after it was made up. This time 5 c.c.

TABLE XV.

Imbibition per Hour per Gram of Dry Weight of Gelatine from Disks of Jelly (28 per cent. Gelatine to 72 per cent. Water) Which Have Absorbed in the Cold Equal Volumes of the Following: (A) Distilled Water; (B) Molecular, Sodium Bromide; (C) Molecular, Sodium Chloride; (D) Molecular, Sugar; (E) One-half Molecular, Sodium Citrate; (F) One-half Molecular Sodium Sulphate; (G) One-half Molecular, Hydrochloric Acid, all Imbibing Water. No Evaporation of Water Took Place from the Gelatine. Ratios Calculated from the Averages of Duplicates Appear in Brackets Below Numbers.

Hours	A		B		C	
	1	2	1	2	1	2
0-1	0.23	0.23	0.35	0.35	0.35	0.35
	(1.00)		(1.52)		(1.52)	
1-3	0.12	0.10	0.14	0.14	0.11	0.13
	(1.0)		(1.3)		(1.1)	
3-27	0.29	0.027	0.041	0.041	0.039	0.043
	(1.00)		(1.46)		(1.46)	
27-51	0.0059	0.0059	0.0076	0.0076	0.0060	0.0068
	(1.00)		(1.29)		(1.08)	

Hours	D		E		F		G	
	1	2	1	2	1	2	1	2
0-1	0.34	0.33	0.47	0.51	0.41	0.36	0.34	0.35
	(1.45)		(2.13)		(1.65)		(1.50)	
1-3	0.14	0.13	0.17	0.18	0.14	0.15	0.11	0.11
	(1.2)		(1.6)		(1.3)		(1.0)	
3-27	0.030	0.025	0.040	0.039	0.046	0.042	0.030	0.034
	(0.98)		(1.43)		(1.57)		(1.14)	
27-51	0.0030	0.0026	0.0072	0.0077	0.0076	0.0080	0.0053	0.0059
	(0.47)		(1.27)		(1.32)		(0.95)	

of the liquid gelatine were placed in the small cylinders, and as soon as the material had set, 1 c.c. of each was spread evenly over the top of the disks. After the solution had been completely absorbed the disks were allowed to stand for twenty-four hours and then water was poured over the top without disturbing the position of the disks in their dishes (for details of this method see page 324). These results agree with those given in Table XIV. Thus it is seen that the evaporation to dryness of the gelatine does not influence the effect of these substances on imbibition.

TABLE XVI, PT. I.

Imbibition per Hour per Gram of Dry Gelatine for Gelatine Jelly (28 per cent. Gelatine, 72 per cent. Water) Under Three Different Temperature Conditions. Ratios Calculated from the Averages of Duplicates Appear in Parentheses Beneath Numbers. Disks.

Hours	10° C.			20° C.		32° C.		
	No. 13	No. 14	No. 20	No. 10	No. 12	No. 5	No. 7	No. 8
0-1.......	0.70	0.69 (1.00)	0.63	0.93 (1.34)	0.87	1.45	1.47 (2.19)	1.49
1-3.......	0.38	0.33 (1.00)	0.28	0.59 (1.71)	0.54	0.63	0.59 (1.91)	0.67
3-8.......	0.19	0.13 (1.00)	0.15	0.27 (1.65)	0.26	0.43	0.40 (2.50)	0.38
8-20......	0.06	0.05 (1.0)	0.05	0.10 (2.0)	0.11	0.18	0.20 (3.7)	0.17
20-26......	0.03	0.01 (1.0)	0.03	0.03 (1.3)	0.03	0.12	0.10 (4.7)	0.11
26-51......	0.01	0.01 (1.0)	0.01	0.03 (3.0)	0.03	0.04	0.03 (4.0)	0.05
51-67......	0.007	0.007 (1.0)	0.007	0.03 (4.0)	0.03	0.04	0.03 (5.0)	0.04
67-90......	0.007	0.007 (1.0)	0.010	0.01 (1.4)	0.01	0.04	Bacteria	Bacteria
90-113.....	0.000	0.000	0.000	0.005	0.004	Bacteria		
113-137.....	0.000	0.000	0.000	0.000	0.000			
137−152 ..	−0.011	−0.005	0.000	0.000	0.000			
152-200.....	−0.010	−0.01	0.000	Bacteria				

TABLE XVI, PT. II.

Water-content of Material Used in Table XVI, Pt. I, at the Points of Approximate Equilibria.

	10° C.			20° C.		32° C.		
	No. 13	No. 14	No. 20	No. 10	No. 12	No. 5	No. 7	No. 8
....	3.93	3.83 (1.00)	4.20	6.14 (1.5 3)	6.02	10.66 .42	8.62 (2)	

All of the experiments with substances from the Hofmeister series show that it is necessary to exercise great caution in drawing conclusions concerning biological behavior from experiments on the imbibition of gelatine. Obviously, in the light of this work, it is absurd to conclude that the accumulation of sodium citrate in the protein jelly of living tissue causes a decrease in its imbibitional capacity because gelatine absorbs less water from a solution of sodium citrate than from water. It may be seen that caution is needed likewise in drawing conclusions regarding the theory of imbibition itself, when the passage quoted above (p. 329) from Taylor regarding the relation of the modulus of elasticity to imbibition is viewed in the light of the results I have here obtained. *It is, then, not safe to draw conclusions regarding the effect which substances within a jelly exert upon its imbibitional capacity, when the evidence for such a conclusion lies in the known effect of an external solution of the same substance on that same or other jellies.*

The facts brought out in this paper, and a former one, relating to the effect of evaporation, of heat, and of salt solutions on the imbibition of water by gelatine offer several suggestions for a theory for the mechanism of the entrance of water into gelatine, but it seems to me that the time is not yet ripe for the formulation of such a theory, especially since new facts are appearing almost daily from various sources.

SUMMARY.

1. Within the temperature range 10°–35° C. heat favors the imbibition of water by gelatine, although the reaction is exothermic. This is not a contradiction of Le Chatelier's theorem regarding the effect of heat on equilibrium in chemical systems, because the reaction reaches only an apparent and not a true equilibrium.

2. When dry gelatine is made up to a jelly with any of the solutions mentioned below, instead of with water, or when gelatine jelly contained 72 per cent. water is allowed to completely absorb one-fifth to three-tenths its own volume of these solutions at 10°–35° C., the imbibitional properties of the gelatine are so changed that the rate of uptake of water is increased. These solutions are: molecular ammonium chloride; molecular sodium chloride; molecular sodium bromide; twice molecular, and molec-

ular ethyl alcohol; twice molecular, and molecular sodium citrate; twice molecular, and molecular sodium tartrate; molecular, and half molecular sodium sulphate. When dry gelatine is made up to a jelly with water and placed in these solutions and the rates of imbibition compared with the rate in distilled water, the results are found to agree with those of Hofmeister. That is, the rate of imbibition of water by gelatine jelly is greater for ammonium chloride, sodium chloride, and sodium bromide than for distilled water, and less for ethyl alcohol, sodium citrate, sodium tartrate, and sodium sulphate than for distilled water.

3. Therefore, it is not safe to draw conclusions regarding the effect which substances within a jelly exert upon its imbibitional capacity, when the evidence for such a conclusion lies in the known effect of an external solution of the same substance on that same or other jellies. All theories based on such assumptions are open to criticism. This applies to the theories involving the physico-chemical causes of the effect of the materials on the gelatine itself, as well as those concerning physiological phenomena.

A Review of Electric Arc Welding. J. A. SEEDE. (*General Electric Review,* vol. 21, No. 13, p. 881, December, 1918.)—As originally practised, arc welding was a rather crude process consisting in drawing an arc about an inch long from a carbon electrode to the work, and feeding the welding in the form of a welding rod similar to the ordinary soldering process. The work produced was very rough and the process was mainly used in such work as filling blowholes and other defects in castings and forgings, and building up metal removed through errors in workmanship.

Later, better results were obtained by drawing the arc from the welding metal, doing away with the carbon electrode. The new process proved considerably more difficult than the old one, as the arc was considerably shorter, having approximately one-half the voltage drop, and therefore more sensitive and more difficult to maintain so as to produce good results. Despite this and other difficulties steady progress was made, and metallic electrode welding soon began to be used for such important work as repairs on boilers of locomotives, vessels and for many other applications requiring comparatively high tensile strength with some ductility. It may be prophesied, without fear of contradiction, that the near future will bring many applications of arc welding in an ever-expanding field.

Crisis in the American Potash Industry. ANON. (*U. S. Geological Survey Press Bulletin,* No. 397, February, 1919.)—The present is a critical time for the potash industry recently established in the United States, according to H. S. Gale, of the U. S. Geological Survey, Department of the Interior. Prior to the war this country used more than a million tons (gross weight) of potash salts each year, and it has been supposed that the cutting off of a large part of this supply was a keen deprivation, particularly to the farmer, by whom it was used for fertilizer. This foreign supply has not been available during the war, and with much energy and enthusiasm a domestic production equivalent to about one-fourth the former importation has been built up. Now, however, it is unexpectedly disclosed that there is little or no market for potash either at the high prices that have prevailed or even at a considerably lower price. No satisfactory explanation of this situation seems to be offered.

Approximately 100,000 tons (gross weight) of potash salts, produced in Nebraska in 1918, are reported as lying in storage warehouses, distributed throughout the southeastern states, which is the region where potash is principally consumed. This is of the same quality that was used in 1917 and is immediately available to the fertilizer manufacturer or the farmer. Potash of other sorts from various sources is also reported unsold, though in smaller quantities. As this surplus represents approximately half the relatively small domestic production and as potash from foreign sources has not been available during the year, it is difficult to explain this apparent lack of interest in the present small domestic supply.

Potash is a term commonly used in referring to the miscellaneous materials carrying potassium which are used or valued chiefly for the potassium contained in them. In 1913, the last year before the war, there was imported into the United States 1,092,588 short tons (gross weight) of the miscellaneous potash-bearing materials, equivalent to 270,720 short tons of "pure" or "actual" potash. This includes the figures for the following salts: Kainite, manure salts, chloride (muriate), sulphate, bicarbonate, bitartrate (argol), bitartrate (cream of tartar), carbonate (crude, crude black salts and refined), caustic chlorate, chromate, bichromate, ferrocyanide (yellow prussiate), ferricyanide (red prussiate), iodide, nitrate (saltpeter, crude and refined), permanganate and Rochelle salts.

Since 1913 the imports of these substances have greatly decreased, until during 1916 and 1917 the total gross weight of potash salts imported was only about 25,000 short tons, containing about 8000 tons of "actual" potash. By far the greater part of potash formerly imported came from Germany, but some of the substances named in the list have come from other places and were received even during the war.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ANNUAL REPORT OF THE DIRECTOR.

[ABSTRACT.]

THE functions of the National Bureau of Standards are the development, construction, custody and maintenance of reference and working standards and their intercomparison, improvement and application in science, engineering, industry and commerce.

When the United States entered the war this service already possessed exceptional facilities, equipment and personnel for exact scientific research in physics, chemistry and engineering. This enabled it to take up promptly many important military researches. The bureau, indeed, coöperated with the army and navy, prior to the war, in the development of radio apparatus, in developing automatic devices for recording battleship target practice, the design of optical systems for submarine periscopes and other purposes, the testing of all kinds of supplies, and the furnishing of data in electricity, heat, light, engineering and chemistry.

In anticipation of demands the bureau before the war had begun special researches known to be required. The urgency of many of these problems was not realized even by those in close touch with the situation. The absolute cutting off of the optical-glass supply, the failure of the linen supply, the total lack of ship chronometers and the necessary uses of light alloys are examples. The rapidity with which the military researches were prosecuted is gratifying, as is the fine spirit of coöperation exhibited. The one thought has been the fullest aid where science could help win the war. The expansion of the bureau to meet the new demands engaged the most serious attention of the staff, and men and facilities were freely furnished for military work. Practically every section of the bureau's regular organization has had military problems of the most pressing nature submitted to it, and invaluable service has been rendered.

The recent expansion of the bureau has been on lines vital to the success of the war. It is interesting to note, however, that many of these lines are of essential value to our industries in peace. The need for the national provision for master-gauge standardization was only realized by those in close touch with such work. The establishment of a gauge-standardization laboratory has proven an important aid to the mechanical industries. The accurate dimensioning of the functioning parts of mechanisms will permit extending the American system of manufacturing interchangeable parts to its maximum usefulness. The importance of nation-wide standardization has long been known, but the practical working out of such standardization is best met by a national laboratory such as the Bureau of Standards. The same principle holds for all the technologies and special branches of physics. The researches now being conducted for war purposes will prove of inestimable permanent value for the general welfare.

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* Communicated by the Director.

AERONAUTICAL RESEARCH.

During the year scientific problems in nearly all branches of aeronautics have been investigated by the bureau, comprising material, design, power sources and technical data. The work is being done in coöperation with the National Advisory Committee for Aeronautics and the military departments of the Government. The primary researches include the development of systems of laboratory tests of all details of airplane design, such as materials, construction, efficiency of form, motor performance, the efficiency of lubrication, carburetion, ignition, choice of fuel, propeller and plane performance, measuring instruments and the appliances and physical constants required throughout for control. These and other pertinent airplane investigations were taken up in the laboratories of the bureau under closely simulated service conditions, embracing such factors as air pressure and air movement, temperature, vibration, humidity, etc.

The engineering testing and investigation covered airplane parts, the use of spruce in airplane construction and mahogany for propellers, the development of instruments for measuring the tension in airplane cables, study of shock-absorbing wheels for airplanes and sea planes, and many others.

A unique feature of the airplane-research program now under way is the development, in connection with the National Advisory Committee for Aeronautics, of a system of free-flight tests made in normal flying as actually practiced by army aviators. Here the problem is to develop a series of autographic instruments which during free flight will furnish the primary data for a scientific study of the theory on which airplanes are designed. The six autographic instruments have been designed at the laboratories of the Bureau of Standards, and three have been completed. These will furnish, without any attention from the aviator, a continuous graphic time record during the entire period of flight, showing the engine torque, revolutions per minute, propeller thrust, plane speed, angle of attack and inclination with horizon.

The bureau's aeronautical instrument laboratory had done fundamental work on the theory of the altimeter and had been testing such instruments for several years before the war began. The staff was promptly increased and now consists of about thirty-five men. The work of this section is to discover sources of error or improvement in the instruments on which aviators depend for aerial navigation, scouting, fighting and bombing, and to develop standard testing methods. In one instance the bureau's tests caused the rejection of 5000 altimeters.

The bureau is now engaged in further researches to promote the operative efficiency of these devices. It has been in close touch with the manufacturing industries in order to make these instruments more reliable and to guard especially against errors due to low temperature, vibration and centrifugal effects occurring during the banking of planes. New kinds of dynamometers, for example, have been designed.

Information gained by this section has been given in lectures to aviation officers supplemented by laboratory demonstrations. Many technical conferences with those concerned have been the means of furnishing a great deal of information. Reports have been made covering many aspects of aviation instruments. The bureau furnished the data upon which the specifications for aviation instruments were drawn for the Signal Corps. The bureau's experts visit the factories and the factory experts visit the bureau for coöperation in overcoming errors and improving output. The bureau staff has not only conducted theoretical and experimental researches in the laboratory under simulated service conditions, but its experts have also studied the instruments in actual flight, including air-speed meters and dynamometers.

The work of aeronautical research required special attention to be given to aerodynamics. A special laboratory for this purpose was built, containing a wind tunnel provided with a wind stream maintained by a 9-foot propeller mounted directly upon the shaft of a 100-horsepower motor. Air speeds of 90 miles were obtained in this tunnel. The purpose of the wind tunnel is to test measuring instruments used on airplanes, to study the design of airplane parts, stabilizing control devices, the efficiency of stream lines, plane sections, etc. For example, the tests included models of airplane and dirigible air-speed indicators, bomb-dropping devices, characteristics of aerial bombs in the wind tunnel and the like. Incidental uses of the wind tunnel have been made in the study of wind stresses on telephone, telegraph and electric-power wires coated with ice and the efficiency of ventilators.

AIRPLANE POWER PLANTS.

At the beginning of the fiscal year research on airplane motor problems, such as the radiator and spark plug design problem, was already under way; this work has greatly expanded and many research problems on aeronautic power plants and accessories have been taken up. An altitude laboratory has been built and put in operation, in which aeronautic engines can be tested at the atmospheric pressures and temperatures encountered at high altitudes under service conditions in warfare. One hundred and twenty sets of observations have been made and results of great importance secured. A dynamometer laboratory has been constructed and equipped with a 400-horsepower dynamometer. This has been of special service in the spark-plug and lubrication investigations.

The effective operation of airplanes at the front depends upon perfecting the essential functioning parts of the engine and also upon the maintenance of the most efficient adjustment of carburetor, lubrication, etc., at all altitudes. The bureau's work has covered both the design and the working characteristics. A study has been made in particular of spark plugs. Fifty compositions of porcelain were made and studied, and the porcelain which showed the highest performance was selected. In operating the spark plug it became essential to study the various types of magnetos, and favorable results have been obtained. The results of the ignition investigations are being utilized by manufacturers and the various military bureaus.

The bureau was enabled to locate serious faults with the carbureting systems when operated at high altitudes, and, as a result, a radical improvement may now be expected in this equipment.

More than 100 radiator designs for airplane use were tested out. New features are to be undertaken with a view to the most effective design. Valuable results have been obtained in the investigation of lubricants, and since the lubricating problem is a vital factor in airplanes, these results are important in that field. Tests have been made of various models of the Hispana-Suiza and Liberty motors as to performance, durability, lubrication, etc.

STANDARDIZATION OF MUNITIONS MASTER GAUGES.

A particularly urgent need upon our entrance into the war was for an adequate supply of standardized master gauges for making munitions. Such gauges are a fundamental requisite. The bureau had already begun such gauge work in its weights and measures laboratories. A matter so vital to the increase in munitions called for by the declaration of war caused the bureau to anticipate this need, and it actively prepared to take up the work to meet the demand to come from the military departments and munitions industries. The rapid organization of the technical and mechanical force to handle the great variety of gauges required for producing munitions has been a fine achievement; its success is unqualified. The bureau's chief expert in charge has entered the military service to coöperate in this work of gauge testing for the arsenals and munitions plants. Before the war only one member of the bureau staff was engaged in this work; at the close of the fiscal year a staff of 140 was busy in it. A branch gauge laboratory has been established in New York City, and laboratories in Cleveland, Ohio, and Bridgeport, Conn., are to be opened soon.

OPTICAL INSTRUMENTS AND LIGHT.

The bureau's optical staff has rendered most important service in connection with the war. This includes the manufacture of optical glass, the design and construction of new optical instruments for military purposes, the testing of such instruments and others purchased for war use, and also highly technical work on radiometry, spectroscopy and colorimetry.

The technical staff in optics has aided in the design of optical systems for periscopes, airplane cameras, long-distance cameras, gun-sight telescopes, stadimeter telescopes, field glasses, etc. The bureau has especialy coöperated to bring about quantity production of the instruments essential to the army and navy. More than 2000 instruments and parts have been tested. These are mainly American instruments made of American optical glass. The high standard of perfection attained is a gratifying result of the active coöperation between the military departments, the bureau and the industries.

Closely related to the above are the applications of optical methods during the year to the measurement of the expansion of such materials as standard steel gauges, fused quartz and optical glass. The bureau has perfected instruments and methods for standardizing methods of turbidimetry, a new and important branch of measurement applicable, for example, to smoke, fog, dusty gases, muddy rivers, ocean turbidity, and the special cases of optical glass, crystals, opal and milk glass; in fact, wherever solid suspensions are an important factor. The industrial applications include tanning, dyeing, paper manufacture, a control of city water filtration, the regulation of the maximum smoke and dust permitted to be discharged into the atmosphere in the cities, and numerous others.

With the advent of the war foreign sources of optical glass were cut off, and, of course, no German glass could be obtained. The French and English needed every pound of their own production and were unable to meet their own requirements. The problem of producing glass of the kinds and qualities required for military purposes was a most serious one. The need for the most perfect obtainable binoculars, camera lenses, optical systems for periscopes, range finders, and optical glass for other purposes could scarcely be overstated, as in a very real sense such optical glass products are the eyes of the military services.

At the time we entered the war the bureau had been actively interested for several years in the problem of producing optical glass in the United States. It was believed that this country could be a producer of optical glass, and the bureau planned to do its part in stimulating such production, both by experiment and research and by the closest possible coöperation with the industries concerned. When we became a belligerent the problem was no longer one of national pride or revenue or independence of foreign supplies. The production of optical glass in America became an acute, vital and immediate necessity. The bureau, therefore, promptly expanded its force and assigned the needed assistance to the existing glass section of the bureau, with instructions to develop the methods of producing optical glasses of all varieties required, on a commercial scale. The technical literature contained a sufficient variety of acceptable formulas, but little as to technique. Experiments were conducted by the bureau, and every detail of the manufacture was worked out by study of theory, by actual experiment and by the study of each factor affecting the optical quality of the glasses produced. The result was gratifying. The bureau has developed the types of optical glass required for military purposes in the war, and has produced them on a commercial scale. It is now supplying optical glass in quantities made in its own shops to be used for the manufacture of optical instruments. The glass is of excellent quality. The bureau also made the clay pots in which the glass was melted. Strangely enough, the problem of producing suitable clay pots for the purpose was one of the fundamental problems in quality production—one which had not been solved by private manufacturers. The bureau determined the clays suitable and the methods of making the glass pots. It actually produced the pots in the quantity required for its own work and furnished the industries with directions for making them.

The bureau has fully coöperated with all glassmakers in producing a supply adequate for war purposes.

Important investigations in radiometry have been made during the year. Standards of radiation in absolute measure were intercompared. Methods were developed for measurements required in the life tests of incandescent lamps. The effect of radiation on balloon fabrics was studied experimentally. The rising temperature of the fabric when exposed to solar radiation was measured, using the precision thermocouple. A small-size model balloon is now being used for this study. Extensive data have been obtained of the photo-electric sensitivity of molybdenite, in view of possible applications of these properties. The bureau's work on glasses for protecting the eyes from injurious radiations has been extended by gathering new data on the transmission of the invisible ultra-violet and infra-red radiations. The bureau has furnished data on various phases of radiation for military applications.

MINE AND RAILROAD-TRACK SCALES.

The mine-scale work of the Bureau of Standards, for which Congress made special provision for a nation-wide investigation, is of special interest, in view of the need for maximum output of coal at the mines. Disputes over weighings cause strikes, loss of time and reduced output. The bureau experts were called upon, and they found the conditions wholly unsatisfactory. In one case a 2-ton scale was 616 pounds in error against the miner. Improper installation, faulty methods of weighing and errors were corrected and mines greatly improved. Indictments were found and fines imposed on the evidence of bureau experts. A general awakening and improvement have resulted, and the prevention of strikes and the renewed satisfaction of the miner have gone far to maintain conditions favorable to a maximum output of coal at the mines.

STANDARDIZATION OF TIMEPIECES.

The time laboratory of the bureau maintains a precision standard clock of the Riefler type, corrected from the noon signals from the Naval Observatory. The bureau's clock in a recent 54-day run exhibited remarkable accuracy, maintaining a constant rate within 0.15 of a second and a net change of rate during the 54 days of 0.01 of a second. The standard clock is connected electrically with the laboratories, which require precise time measurements.

SOUND AND ACOUSTICS.

An interesting feature of the bureau's work has been the development of its laboratory for the study of sound. This has been placed upon a practical basis during the year by the acquisition of much-needed equipment. The applications of acoustics to warfare have been quite important. These include elements in the problems of sound ranging and the detection of submarines, airplanes and enemy operations by acoustic methods. Devices have been perfected which analyze sounds into their components. A special study has been made in the sound laboratory of the photographic analysis of sound waves with particular reference to the improvement of airplane-engine mufflers.

ELECTRICAL RESEARCH AND TESTING.

The electrical work of the bureau is of two kinds—first, the establishment and maintenance of fundamental standards for all electrical measurements used in research and engineering (involving researches in the most refined methods of measurements and the most delicate and precise apparatus); and, secondly, engineering applications of electricity, including a limited amount of testing of commercial instruments and products. All this work is important for the business of war as well as that of peace. Important service was rendered to the military departments in the standardization of electrical equipment for military use, the formulation of proper specifications for the purchase and testing of such equipment, and the development of new and hitherto unavailable equipment for the new exigencies. The bureau made tests of electrical blasting devices for firing trench mortars and mines, and redesigned these machines with great reduction in their weight and cost and increase in their reliability. Extensive investigations of the electrical ignition systems for airplane and other gasoline engines have been carried out. This, combined with the bureau's work in ceramics, has resulted in a great improvement in the quality of spark plugs made in this country. An extensive comparison of magneto and battery systems of ignition has also been made with the promise of marked improvement. Specifications have been prepared and revised after experimental laboratory work under controlled temperature conditions. The large number of such batteries used for military purposes and the extreme importance of their unvarying and proper functioning make this problem one of unusual importance and urgency.

In the field of special illuminants the bureau was able to assist the military departments in developing trench flares, portable acetylene lights and field searchlights. The bureau is testing self-luminous paints. Radium has had direct application to military uses as a component of self-luminous materials employed extensively on the dials of aeronautic and other instruments used at night. In the important field of X-rays special attention has been given to the development of protective materials to safeguard the users of X-ray equipment, and gratifying results have been obtained in the improvement of this class of material. The novel methods of magnetic analysis developed at the bureau for testing steel rails and other magnetic materials are now being used in testing steel for rifle barrels, with the object of materially speeding up the production of rifles.

Special equipment has been designed for the measurement of the velocity of projectiles, and the bureau has contributed in no small part to the methods now in regular use for this purpose. Another important field in which successful work has been done is the development of equipment for locating hostile batteries on land and for detecting subterranean sounds. In the field of radio communication the bureau has contributed the designs of various instruments, has made extensive tests of materials for use in such apparatus and has contributed large numbers of completed instruments. It has served also as a source of supply for highly trained men for the military radio service and has prepared circulars which are serving as the most-up-to-date textbooks in the service radio schools.

HEAT AND TEMPERATURE.

The important applications of heat measurements in the industries and the need for standardized equipment for this purpose have made the heat laboratories of the bureau of special service to industries engaged in the technology of materials and in technologic research generally.

An important investigation of the fire-resisting properties of structural materials has been conducted to furnish architects, construction engineers, builders, State and city building bureaus, insurance interests and others with basic data for the efficient design of structures with a view to a minimum fire loss. In the study of fire-resistive properties of materials structural steel columns were specially investigated. Many such columns with and without protective coating were tested in a specially devised furnace. The research showed that unprotected columns which would fail in half an hour, if properly protected by concrete or other material would remain intact for eight hours. The resistive properties of concrete columns was found to depend largely upon the aggregate used. Quartz aggregate proved specially resistive. Seventy-five steel and iron columns were tested during the year, all designed according to standard current practice with a view to excellent workmanship.

In addition to the above, 40 columns of reinforced concrete were submitted to fire test. The columns were subjected to pressure such as is encountered in structures and were mounted within a gas-fired furnace. Valuable results were obtained which will greatly aid in the effective design for similar columns in actual use. The column research is typical of the bureau's investigation of the fire-resistive properties of materials. It has already yielded valuable information and promises further results of importance to the building industries.

RESEARCHES ON METALS AND ALLOYS.

Metals are so vital a factor in the war that the division on metallurgy has been able to render important service. During the year a new building was completed for the metallurgical work, which is now installed in its new quarters. This laboratory contains a foundry, heat-treating and mechanical plant, rolling mill, power presses, shearing equipment, drawing bench for drawing metal tubes, and a machine shop, thus enabling the bureau to prepare and investigate alloys, both ferrous and nonferrous, of all kinds.

The year's work comprised the examination of gun metals, light alloys for aircraft, many alloys for special military uses, and pure metals required for technical purposes. The foundry has made 2249 separate experimental castings during the year. The recent development of light alloys has opened a new chapter in industrial work. The bureau researches on alloys were given special impetus by the visit of its chief expert to the battle front in France for the study of gun metals and aircraft alloys under war conditions. Light alloys are essential in aircraft, where both lightness and strength are required. It developed that metallurgists were unacquainted with the physiochemical data concerning aluminum and its remarkable series of special alloys. Circulars were, therefore, prepared for technical metallurgists and users of such alloys, and a consolidated circular on this important subject is in press. Many compositions in this series were cast and rolled for the bureau and studied in its laboratories.

Substantial progress has been made in the study of fusible metals, the melting points of which control the functioning of such devices as automatic fire sprinklers, safety plugs for steam boilers and others. The output of fusible tin plugs used as safety devices in steam boilers is controlled as to quality by the bureau's researches. The work in metallurgy has covered numerous other subjects. Low tin solders, bronze and bearing metals have been developed to aid the War Industries Board in conserving of tin. The serious erosion of machine-gun barrels was the object of a special technical study.

Experimental work was done to establish standards of uniformity for the copper plugs used in testing powders. Standards of composition and thermal treatment were developed for the special metals used in aeronautic instruments.

In the research foundry methods were developed with respect to standard Government bronze, and details are soon to be published. Standards are being developed for molding sands which we believe will save 90 per cent of the so-called " burnt " sand. A standard method of determining carbon content of steel, devised during the year, permits complete determination in less than five minutes. A convenient method for determining nitrogen has also been devised, as well as new forms for determining other gases.

TESTING OF INSTRUMENTS AND MATERIALS.

Apart from scientific researches and technological studies, the bureau during the year has conducted thousands of tests, many of an investigative character. Examples, in round numbers, will indicate the magnitude of this work. About 18,000 thermometers were tested, including 13,000 clinical thermometers. About 200 tests of thermocouples and pyrometers for high-temperature measurements were made. The metallurgical division made 1289 thermal analyses, heat treatment and other kinds of metal tests, besides more than 2000 separate castings for experimental purposes. About 2000 tests on military optical instruments were made in the optical laboratories. The chemical work included 18,000 chemical tests during the year. It is now growing rapidly, and 30,000 tests will probably be made during the coming year. The bureau certified 3,500,000 barrels of cement for the Government departments and tested more than 5000 timepieces, nearly 3000 pieces of volumetric apparatus and 28,000 precision gauges.

MATERIALS.

The measurement and investigation of the properties of materials have in recent industrial practice become a vital necessity. In no other way than by an exact knowledge of these properties can high efficiency be had. The successful war work of the bureau was possible because it had *already* studied the properties of materials used from a military point of view—for example, optical glass, light alloys, gun metal, cotton fabricated as substitute for linen in airplanes, low tin solders, and the like.

CHEMISTRY.

The chemical work of the bureau was transferred to the new chemical laboratory early during the year. The staff has expanded from 58 to 146, partly by the detail of chemists from the army to assist in military testing and research. The work has already outgrown its new quarters, and the laboratory is now housing 25 per cent. more work than was planned for it.

STANDARDIZATION OF SUGAR TECHNOLOGY.

Owing to the necessity of increasing to the greatest possible degree the American output of sugar, the entire machinery of the industry is overtaxed and upset. Many new problems demanding solution at the earliest possible date have arisen. Additional facilities and assistance were required to attack them. In order to begin the work Congress granted an appropriation of $20,000 to be used for the standardizing of sugar-testing apparatus and the development of technical specifications for the various grades of sugar with particular reference to problems made pressing by war conditions.

The United States has the largest and most diversified sugar industry in the world, including, as it does, the cane and beet industries, a great refining industry, a maple-sugar industry, a large sirup industry and a very important Government interest due to the collection of a revenue from an import duty. The widespread demand for technical assistance in these matters is shown by the fact that an entire edition of 1500 copies of the Bureau of Standards' circular was purchased by the public in less than three weeks.

THE BUREAU'S WORK FOR THE SOLDIER.

The applications of science to military uses are illustrated by several examples of the bureau's work directly affecting the comfort and efficiency of the soldier. The soldier's shoes are investigated in the laboratory and in the field to determine the most suitable leather. A sole leather testing machine is used, and the leather is chemically investigated while controlled service tests are in progress by the soldiers in camp. The serviceability of shoestrings has also been under test. Uniform cloth has been under careful investigation for some time in the textile laboratories of the bureau. An expert was dispatched from the bureau to England and France to study the quality and serviceability of army uniform material, while in the laboratory the bureau has been making searching examinations of the various fabrics designed and submitted. It has assisted in developing and selecting from the available materials the present standard uniform button.

The heat conductivity of the soldier's blanket has been studied. Cotton blankets may equal wool blankets in this respect. The bureau has investigated shelter tents, the soldier's canteen and other kit equipment, washing and shaving soaps, combs, inks and other supplies for the soldier's use.

The bureau also determined by careful tests the most suitable trench oil stove, taking account not only of its heating efficiency, but the danger of observation from the light radiated on the ground. It has standardized the gauges for making the service rifle, has studied the problem of gun erosion and the failure of gun parts and material in service. All the men in the navy carry an identification tag devised by and prepared according to specifications developed by the Bureau of Standards. In short, there is scarcely a phase of the soldier's needs and activities in which the bureau has not coöperated with the military departments to secure the most effective provision for his comfort, convenience and fighting power.

THE METRIC SYSTEM.

The War Department early in the war decided to adopt the metric system for use in connection with maps and gun-firing data. The Ordnance Department has also adopted standard metric-dimensioned guns, such as the 37-millimeter, 75-millimeter and 155-millimeter models, and this involves corresponding changes in shell sizes. These uses of the metric system made it desirable that the Bureau of Standards issue for the information of the soldier a small manual.

ALUMINUM AND ITS LIGHT ALLOYS.*

This circular attempts to give all available information concerning the physical and mechanical properties of aluminum and its light alloys in summarized form. Commercial alloys are described and compared. The corrosion and disintegration of aluminum and its alloys is considered and the circular is concluded with a complete bibliography of the subject.

SILICA REFRACTORIES, FACTORS AFFECTING THEIR QUALITY AND METHODS OF TESTING THE RAW MATERIALS AND FINISHED WARE.†

[ABSTRACT.]

The quartz or amorphous silica of raw silica brick is gradually transformed to crystal forms of lower specific gravity when the brick are burned, and subsequently when the brick are heated in use. This work was carried out primarily to obtain a means of simply yet accurately determining the degree to which this transformation has taken place in any given material. In the course of the work, however, some points concerning raw materials and method of manufacture have also been touched upon. The quartzites are first considered, then manufacture, and lastly properties of finished silica brick and methods of testing them.

By far the larger part of the silica brick manufactured in all countries are made from quartzites of comparatively early geologic age. Although in some cases amorphous (noncrystalline) silica, chalcedony, chert, and sand or pebbles cemented together with chalcedony have also been used. Suitable quartzites range from hard, highly metamorphosed varieties having tightly interlocking grains to medium soft rock, which is slightly porous. Loose grained quartzites and sandstones are, however, of little value. Quartzites that are now being used range from very young rocks back to the oldest sedimentaries.

As possible improvements (for certain materials) in the method of grinding and molding silica brick the use of sized material mixed in a machine similar to a batch concrete mixer to avoid further crushing of the grains as much as possible, and machine molded with a pressure of approximately 1500 pounds per square inch is suggested.

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* Bureau of Standards Circular No. 76.

† Technologic Papers No. 116.

Owing to the present tremendous demand for silica refractories, the tendency is to burn them as rapidly as possible to a temperature approximately equivalent to that required to cause Orton's pyrometric cone 18 to bend over. The experiments conducted in this study show that at temperatures from 1250° to 1350°C. there is a slight fluxing or drawing together of the particles of a raw brick, and that at these temperatures transformation of quartz to the forms of lower specific gravity takes place at a moderate rate. Thus, these temperatures insure minimum porosity and a medium rate of transformation. At higher temperatures, however, the transformation takes place rapidly, causing the porosity of the brick to increase unduly. The possible improvement in method of burning silica brick given below is based on the data gathered during the experiments, and is as follows. The temperature is gradually raised to 1250° C. in the usual manner and is then kept at from 1250° to 1350° C. for several days, at the end of which time it is gradually raised until cone 18 to 20 bends over.

The heating tests with raw commercial bricks brought out the fact that mixes made from the principal commercial quartzites all transform at approximately the same rate at temperatures from 1200° to 1500° C. and that the final specific gravities of all are very close together and in the neighborhood of 2.30. However, bricks made in the usual way from pure chert rock transform much more rapidly than do bricks made from quartzite, and the resulting brick is high in tridymite (crystal form of silica with specific gravity 2.270). Such chert brick when well burned, may prove of value in work which is subject to rapid changes of temperature. The heating tests also showed that the transformation taking place in commercially burned bricks on being reheated are essentially the same as those taking place in raw mixes. Thus, when underburned brick are heated for extended periods to 1200° C. or higher, as in byproduct coke ovens or gas benches, any quartz present will transform and cause an expansion of the exterior volume of the piece except as this expansion may be in part counteracted by drawing together of the particles of the brick due to soaking at high temperatures.

The specific gravities and porosities of most of the leading varieties of commercial silica brick have been determined, and all varieties thus far tested have specific gravities between 2.650 (the specific gravity of quartz) and 2.270 (the specific gravity of tridymite). Brick made from chert rock, when well burned, have a specific gravity very close to this lower limit. The average specific gravity of all varieties so far tested is 2.384 and the average porosity of the same is 26.34 per cent. The limits of porosity found are 22.6 and 31.5 per cent.

The results of our own work in this connection and more recently that of other active operators in the testing of silica refractories, indicate that the relative position of the specific gravity of a silica brick between 2.65 and 2.270 is a definite indicator of the degree to which the brick has been burned, and in conjunction with the porosity, indicates approximately what the subsequent expansion of the brick will be in use. The porosity and specific gravity changes were obtained by computation from the dry weight of the piece, its weight when saturated with water and its weight when suspended in water. Thus, by a simple procedure the manufacturer can keep an accurate check on the nature of the silica brick he is turning out, and in the same way the consumer can determine what to expect from them in use.

Relation between Civil and Military Engineering. W. M. BLACK. (*The J. E. Aldred Lectures on Engineering Practice*, 1917–1918, Johns Hopkins University.)—The fundamentals of the course of study required for a civil engineer of all branches of the profession are the same as those for the military engineer. In military engineering, the officer entrusted with certain work must obtain beforehand all the information he can. He must then lay out the plan he hopes to follow, estimate probable difficulties to be met, and be ready to change this plan at short notice and adapt it to unexpected happenings. This involves a long and special training and a quickness of view and decision which are vital to the success of his work, especially in war. While the civil engineer does not often have to make the instant decisions of the military engineer engaged in actual war, he must, nevertheless, follow the same path in carefully planning his work ahead. In both cases—the civil and the military—the chief requisite to success is the careful study and choice of a suitable plan of work and the ability to meet the changes in conditions which always come. In military work at the front, any materials at hand must be utilized. Economy in cost must be disregarded; economy in time is the essential.

The ability to do certain things in a certain way without knowing clearly why that way is best, or even if it is the best, is poor preparation for an engineer. In the examinations of candidates for the position of Second Lieutenant in the Corps of Engineers of the Army which have been held for some years, some interesting facts have developed. All candidates must be graduates from some approved technical school, and the questions to be answered are such as should be answered by any man who has mastered his course. Yet the proportion passing these examinations is woefully small. At the last examination held, out of 190 candidates, the papers of only 36 could be accepted as up to or approaching the required standard. The failures were not in the most difficult studies only; topographical surveying frequently was a stumbling block. Descriptive geometry was so generally unknown as to create the impression that the value of this subject was underestimated by the schools themselves. It seemed at times as if the whole scheme of education had been at fault, that the scholars had never been compelled to undertake the tasks set and do the allotted work as a duty, whether congenial or not, and further, that the foundation of all, the general knowledge that every man that wants to attain success must have, was lacking.

Efficiency of Commercial Egg Candling. M. K. JENKINS and C. A. BENGSTON. (*U. S. Department of Agriculture, Bulletin 702, September 12, 1918.*)—It is common knowledge among those buying and selling eggs that grading by the candle is not an absolutely dependable method for the separation of good and bad eggs. As it is the best method known for determining the quality of eggs in the shell, however, it is important to learn its degree of efficiency.

The accuracy of candling depends upon the quality of the eggs and the skill of the candlers. With experienced workers, the number of bad eggs found in high-grade eggs after candling is negligible. On the other hand, when a large percentage of the good eggs in the supply have weak whites and yolks and when the percentage of bad eggs runs high, the difficulty of distinguishing between edible and inedible eggs is increased, and the number of bad eggs miscandled is greater. In studies with skilled candlers, the average number of bad eggs miscandled in a case of 30 dozen varied from 0.20 in spring firsts to 10.77 in very low grade refrigerator or cold-storage eggs. The number of bad eggs which could not be found by candling ranged from none to 6.93 per case, depending upon the grade examined. The data, as summarized from another point of view, show that out of 5.985 bad eggs present in 128,587 eggs, 71.65 per cent. were detected by candling, 17.02 per cent. were missed by candling, and 11.33 per cent. were not distinguishable by candling.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE PHYSICAL CHARACTERISTICS OF X-RAY FLUORESCENT INTENSIFYING SCREENS.[1]

By Millard B. Hodgson.

[ABSTRACT.]

THE use of fluorescent screens for the intensification of exposure is of widespread practice and of considerable importance in practical X-ray photography or roentgenology. Also in the work of Hull, St. John and others the fluorescent screen has been employed to reduce the lengthy exposures of such X-ray spectroscopic investigations that are dependent on the photographic plate for record.

In dealing with fluorescent phenomena dependent on an X-ray tube for excitation there are two types to be considered, both of which may be utilized for photographic intensification. The first type is that of true characteristic radiation, the second ultra-violet and visible fluorescent radiation. The true characteristic radiations of all the elements which are feasible to use are within that range of frequencies usually termed X-rays. Hence, the laws pertaining to high frequency radiation govern the photographic use of screens dependent on this principle. In the case of fluorescent emission of ordinary light the laws of ordinary optics apply.

Of these two types of intensifying screens, the second has proven the far more efficient in practical usage.

Of the materials which fluoresce to X-rays in the range of frequencies from the ultra-violet to the red, there are only a few which can be used efficiently for photographic intensification. All of these substances must be in crystalline state. Of these, crystalline calcium tungstate is by far the best with present photographic X-ray materials. The salt is usually powdered and coated with a suitable binder on a support of some material of slight X-ray absorption, such as cardboard or celluloid. This screen is then placed in contact with the photographic surface and exposure made through either the screen or the photographic plate or film.

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* Communicated by the Director.

[1] Communication No. 67 from the Research Laboratory of the Eastman Kodak Company, published in *Physical Review*, December, 1918.

The efficiency of any radiator as a source of photographic stimulation depends primarily on the comparative spectral distribution of the energy of the radiator and the spectral sensibility of the particular photographic plates used. While these relations have not been determined as yet on an equal energy basis for X-ray materials, qualitative analyses have been made.

The fluorescent spectra of calcium tungstate were obtained, using a Hilger quartz spectrograph. A Coolidge tube of medium focus was used, the length of exposures averaging 1000 milliampere minutes at 8-inch distance from the target to the screen.

Spectrograms were made with the tube operating at 40 K. V., 60 K. V. and 80 K. V. (R. M. S.)

It was found in general the fluorescent spectrum of calcium tungstate as used in the screens examined extended from about 3600 to 5200 A. U. at the voltages normally used in radiographic practice. This emission coincides remarkably well with the wavelength sensibility waves of the X-ray plates which are being mostly used.

Testing Permanent Magnets by Means of a Voltmeter. ANON. (*Electrical World*, vol. lxxiii, No. 6, p. 267, February 8, 1919.)—In developing apparatus requiring permanent magnets, the National Safety Appliance Company of San Francisco found no suitable magnets on the market, and undertook to design, build and test large horseshoe magnets suitable for the work in hand. The magnets consisted of several laminations of 3/8 inch by 3 inches by 60 inches forged magnet steel bent into U-shape and bolted together without air-gaps between the laminations. The laminations were bent with the 3-inch face parallel to the plane of the "U."

The magnetometer was built up from a direct-current voltmeter from which the permanent magnet had been removed. Soft Norway iron pole-pieces were fitted to the instrument, their outer ends projecting beyond its base and the inner portion connected in such a way as to take the place of the magnet supplied with the instrument. These pole-pieces were long enough to span the open end of the U-magnet. Tap-bolts were used to attach the magnets to the pole-pieces to secure good contact. A current of known strength was then caused to pass through the moving coil of the instrument, and the deflection of the pointer was read as directly proportional to the magnetic field set up by the magnet on the pole-pieces. The scale was divided into 100 spaces for convenience in taking the reading in terms of percentage of the strength of any magnet adopted as standard.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE ARRANGEMENT OF ELECTRONS IN ATOMS AND MOLECULES.

By Irving Langmuir.

In a paper to be submitted for publication in the *Journal of the American Chemical Society* a theory of the arrangement of electrons in atoms and molecules will be given. This theory, which is essentially an extension of Lewis' theory of the "cubical atom" (*Jour. Amer. Chem. Soc.* 38, 762, 1916), may be most concisely stated in terms of the following postulates:

1. The electrons in atoms are either stationary or rotate, revolve or oscillate about definite positions in the atom. The most stable atoms, namely, those of the inert gases, have positions symmetrical with respect to a plane called the equatorial plane, passing through the nucleus at the center of the atom. No electrons lie in the equatorial plane. There is an axis of symmetry (polar axis) perpendicular to the plane through which four secondary planes of symmetry pass, forming angles of 45° with each other. These atoms thus have the symmetry of a teragonal crystal.

2. The electrons in any given atom are distributed through a series of concentric (nearly) spherical shells, all of equal thickness. Thus the mean radii of the shells form an arithmetic series 1, 2, 3, 4, and the effective areas are in the ratios $1 : 2^2 : 3^2 : 4^2$.

3. Each shell is divided into cellular spaces or cells occupying equal areas in their respective shells and distributed over the surface of the shells according to the symmetry required by postulate 1. The first shell thus contains 2 cells, the second 8, the third 18, and the fourth 32.

4. Each of the cells in the first shell can contain only one electron, but each other cell can contain either one or two. All the inner shells must have their full quotas of electrons before the outside shell can contain any. No cell in the outside layer can

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* Communicated by the Director.

contain two electrons until all the other cells in this layer contain at least one.

5. Two electrons in the same cell do not repel nor attract one another with strong forces. This probably means that there is a magnetic attraction (Parson's magneton theory) which nearly counteracts the electrostatic repulsion.

6. When the number of electrons in the outside layer is small, the arrangement of the electrons is determined by the (magnetic?) attraction of the underlying electrons. But when the number of electrons increases, especially when the layer is nearly complete, the electrostatic repulsion of the underlying electrons and of those in the outside shell becomes predominant.

7. The stable and symmetrical arrangements of electrons corresponding to the inert gases are characterized by strong internal and weak external fields of force. The smaller the atomic number, the weaker the external field.

8. The most stable arrangement of electrons is that of the pair in the helium atom. A stable pair may also be held by: (a) a single hydrogen nucleus; (*b*) two hydrogen nuclei; (*c*) a hydrogen nucleus and the kernel of another atom; (*d*) two atomic kernels (very rare).

9. The next most stable arrangement of electrons is the *octet;* that is, a group of eight electrons like that in the second shell of the neon atom. Any atom with atomic number less than twenty, and which has more than three electrons in its outside layer tends to take up enough electrons to complete its octet.

10. Two octets may hold one ,two, or sometimes three pairs of electrons in common. One octet may share one, two, three or four pairs of its electrons with one, two, three or four other octets. One or more pairs of electrons in an octet may be shared by the corresponding number of hydrogen nuclei. No electron can be shared by more than two octets.

This theory explains the periodic properties of all the elements, including those of the eighth group and the rare earths. It also meets with success in explaining the magnetic properties of the elements, and, in fact, it applies as well to the so-called physical properties, such as boiling points, freezing points, electric conductivity, etc., as it does to the " chemical " properties. It leads to a simple theory of chemical valence applying equally well to polar and to non-polar substances. In the case of organic compounds the results are identical with those of the ordinary valence theory, but with oxygen, nitrogen, chlorine, sulphur and phosphorus compounds the new theory applies as well as to organic compounds, while the ordinary valence theory fails completely.

This theory explains also the structure of compounds which, according to Werner's theory, are second order compounds with a coördination number equal to four. According to the present theory such compounds are to be regarded rather as typical primary valence compounds .

This valence theory is based on the following simple equation:

$$e = 8n - 2p$$

where e is the total number of available electrons in the shells of all the atoms in a molecule; n is the number of octets forming the outside shells, and p is the number of pairs of electrons held in common by the octets. This equation is a complete mathematical statement of the primary valence requirements, not only in organic but in inorganic chemistry.

The inert gases are those in which all the cells in the outside shell have equal numbers of electrons. Thus, according to the first four postulates, helium has two electrons, neon has ten, argon eighteen, krypton thirty-six, xenon fifty-four and niton eighty-six. All atoms with an atomic number greater than that of helium (2) have as their first shell a pair of electrons close to the nucleus. The line connecting the two electrons establishes the polar axis for the atom. Neon has in its second shell eight electrons, four in each hemisphere (*i .e.,* above and below the equatorial plane), arranged symetrically about the polar axis. The eight electrons are thus nearly at the corners of a cube. In argon there are eight more electrons in the second shell. In all elements of higher atomic number the second shell is like that in argon. Krypton has in its third shell nine electrons in each hemisphere, symmetrically placed with respect to the polar axis and to the four electrons in the second shell. The ninth electron in each hemisphere goes into the polar axis. This fact accounts for the position and properties of iron, cobalt and nickel. Xenon is like krypton, except that it has twice as many electrons in its third shell. Niton has sixteen electrons in each hemisphere of its fourth shell. These are easily placed symmetrically with respect to the polar axis and the eight underlying electrons.

This theory leads to very definite conceptions as to the positions of the electrons in the molecules or space lattices of compounds. The structures of molecules of N_2, CO, HCN and NO prove to be exceptional in that the kernels of both atoms in the molecule are contained within a single octet. This accounts for the practically identical "physical" properties of nitrogen and carbon monoxide and for the abnormal inertness of molecular nitrogen.

The results obtained by the use of the postulates are so striking that one may safely reason that the results establish the fundamental correctness of the postulates.

These conclusions, however, are not easily reconciled with Bohr's theory of the atom. Bohr's stationary states have a rather close resemblance to the cellular structure postulated in the present theory. There are also striking points of similarity with J. J. Thomson's theory of the structure of atoms ,in which he assumes that the attractive forces are limited to certain tubes of force. It is probable, however, that the cellular structure is not so much a property of space as of the electron. It seems that the electron must be regarded as a complex structure which undergoes a series of discontinuous changes while it is being bound by the nucleus or kernel of an atom. There seems to be strong evidence that an electron can exert magnetic attractions on other electrons in the atom even when not revolving about the nucleus of the atom.

Paper Driving Belts. ANON. (*Machinery,* vol. xxv, No. 6, February, 1919, p. 497.)—It is said that paper driving belts have been introduced into German workshops. The paper is cut into narrow bands which are then spun, and the belts are made by weaving or braiding. Woven belts are of two kinds—paper fabric and paper thread—the fabric being more often used. The fabric is first cut into bands about 12 feet long, which are subsequently made into the desired width and thickness. A strengthening core is interposed, made of either cotton or sheet metal, though more recently the cores have been made of interwoven paper thread and metal wires. The core is encased in paper strips and the whole is then sewn with strong thread. These belts are said to be very flexible and to wear satisfactorily. The tensile strength is from 560 to 700 pounds per inch of width.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

CRYSTALLOGRAPHY AND OPTICAL PROPERTIES OF THREE ALDOPENTOSES.[1]

By Edgar T. Wherry.

[ABSTRACT.]

THE relations between chemical isomerism and the crystallography and optical properties in the aldopentose group of sugars has been studied. The *a-d* form of lyxose is monoclinic, with prism, front pinacoid, base, and back dome. The corresponding form of xylose is similar, the front pinacoid being absent. β-arabinose is rhombic, but the forms are similar to those on the other sugars, and there are striking similarities in the angles of the three, the angles of the prominent terminal forms and the φ angles of the dominant prism varying less than 2° from one to the other. The optical properties of these forms and also of α-arabinose were measured under the microscope by immersion method, using mixtures of turpentine, clove oil, and monobromnaphthalene of measured refractive indices differing by steps of 0.003, and varying the wave length of the light, obtaining the value for the D-line by interpolation. The results of observation are presented in a standard form which has been found most convenient in practice. A table of dispersions, giving the values of the three indices and the double refraction for six different wave lengths, is also presented. The specific gravities of the several forms were determined by suspension in carbon tetrachlorid and benzene, and from them the refractivities were calculated. The results for all four were practically identical, although they are distinctly less than the theoretical value. Finally, since it may be desirable to distinguish minute crystals of these sugars, a determinative table based on their optical properties is given.

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* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Amer. Chem. Soc.*, v. 40, Dec., 1918, p. 1852.

THE PRODUCTION AND CONSERVATION OF FATS AND OILS IN THE UNITED STATES.[2]

By H. S. Bailey.

Chemist in Charge, Oil, Fat and Wax Laboratory, Bureau of Chemistry, in collaboration with B. E. REUTER, Chief Fats and Oils Division, U. S. Food Administration.

[ABSTRACT.]

U. S. DEPARTMENT OF AGRICULTURE Bulletin 769, "Production and Conservation of Fats and Oils in the United States," recently issued by the Bureau of Chemistry, contains the first adequate survey of statistics on the fat and oil industry. These statistics, which were compiled by the U. S. Food Administration, cover the production, exportation and importation of fats and oils during the past seven years. The processes involved in making the various fats and oils are described briefly, and suggestions made for increasing the present supply and eliminating waste.

THE WEAR RESISTANCE OF LEATHER FROM DIFFERENT PARTS OF THE HIDE.[3]

By F. P. Veitch and J. S. Rogers.

[ABSTRACT.]

ACTUAL wearing experiments, involving 125 pairs of sandals and extending over a period of several months, were conducted with leather soles from different tannages and different sections of the hide. The total thickness of each sole worn away during a recorded number of hours' wear was determined and these results calculated to and expressed as inches wear per 1000 hours. The average losses were as follows: Butt (7 leathers), 0.464; heads (2 leathers), 0.512; shoulder (8 leathers), 0.605; belly (4 leathers), 0.944. Leather from the butt wore on an average at least twice as long as that from the belly portion of the hide, and about one and one-third times as long as that from the shoulder portion. While the results are but preliminary, they substantiate the belief which has been generally held for many years concerning the relative wear resistance of different sections of the hide.

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[2] Department of Agriculture Bulletin 769.

[3] Published in *J. Amer. Leather Chem. Assoc.*, vol. 13, No. 3, March, 1918, pp. 86–90.

THE GLOBULIN OF THE COCONUT, COCOS NUCIFERA. I. THE PREPARATION OF COCONUT GLOBULIN. DISTRIBUTION OF THE BASIC NITROGEN IN COCONUT GLOBULIN.[4]

By Carl O. Johns, A. J. Finks and C. E. F. Gersdorff.

The globulin was extracted, by means of sodium chlorid solution, from coconut meal from which most of the oil had been removed by pressing. The yield was 10 per cent.

The distribution of the basic amino acids in coconut globulin as determined by the Van Slyke method was as follows:

Cystine	1.44 per cent.
Arginine	15.92 per cent.
Histidine	2.42 per cent.
Lysine	5.80 per cent.
Tryptophane	Present.

The percentage of free amino nitrogen on the unhydrolyzed protein was found to be 3.68 per cent. by the method of Van Slyke and Birchard.

Further work on the distribution of the mono-amino acids in coconut globulin is now in progress. Preliminary feeding experiments indicate that the proteins of the coconut are adequate for normal growth.

Latest Developments in the Electric Transmisison of Power. P. M. Lincoln. (*Journal of the Cleveland Engineering Society*, vol. xi, No. 3, p. 153, November, 1918.)—For the long distance transmission of power there is to-day only one method that deserves serious consideration, and that is the electric method. There was a time when the direct current appeared to solve the problem of power transmission. The Brush arc-lighting generators, devised in the early days of electric lighting, were also devoted to some extent to the transmission of power, and the offshoot of that method of conveying electricity is responsible for the direct current installations in existence to-day.

Direct current transmission is not now employed in the United States, but there are some plants in Europe which are transmitting power by means of arrangements exactly similar to the Brush arc lamp system of 1878. That is, they are transmitting power by using constant direct currents over a double line, and when the amount of power changes, the voltage changes. The Swiss engineer Thury is responsible for such direct current transmissions as exist now in the European countries. There are a number in Switzerland and a particularly large one in Southern France with a constant current of something like 500 amperes, and a voltage which at full load reaches 60 or 70 thousand volts; even with that, however, the amount of power distributed is relatively small. Present-day power units are very large. There is one plant in actual operation in the West where the generator units are 17,500 kilowatts each. There are some steam generators actually under construction and others projected of 100,000 horsepower and 75,000 kilowatts. When considering power of this order, the direct current system such as mentioned above is totally inadequate.

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[4] Published in *J Biol. Chem.*, vol. 37, No. 1, Jan., 1919.

Brush first made his arc machine in 1878 and his method of lighting by arcs was developed very rapidly from that time on. The Edison incandescent system was first operated in the downtown section of New York City in 1882. The two methods were naturally considered for power transmission, but both of them fell a great deal short of meeting necessary requirements. The first alternating current transmission that took place in this country was carried on by William Stanley in 1885, who had become interested in the Goulard and Gibbs transformer which was being developed in France. Later the alternating current system was further developed by George Westinghouse, but the system would never have reached its present position without the development of the induction motor invented by Nikola Tesla.

After the year of 1890, the year of the introduction of the induction motor, the development of power transmission by alternating current was very rapid. It was in 1893 that there was put into operation at Pomona, California, a transmission line of about 30 miles at 10,000 volts. Then, in 1895, another 30-mile line was put in at 10,000 volts, and two years later the Telluride Power Company, in Western Colorado, doubled that voltage with 40,000 volts with a transmission distance of 55 miles. The 40,000 volts of the Telluride project remained the highest transmission voltage for five or six years. In 1903 at Guanajuati, Mexico, a transmission system was put in using 60,000 volts, the distance being 105 miles. Five years later, the voltage was increased at Muskegon, Michigan, to 100,000 volts. About four years later, the highest voltage yet installed of 150,000 volts was adopted by the Pacific Light and Power Company, from the mountain back of Fresco, California, to Los Angeles, a distance of about 240 miles. To date, that remains the highest that has yet been put into actual operation. However, 200,000 volts is being seriously considered by a number of companies, and probably not many years will pass before the 200,000 volt transmission will be in actual use.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, February 19, 1919.)

Hall of The Franklin Institute,
Philadelphia, February 19, 1919.

President Dr. Walton Clark *in the Chair.*

Additions to membership since last report: 13.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

The standing committees for the year 1919–1920 were announced.

Mr. Benjamin Franklin, Chairman of the Committee on Science and the Arts, introduced Mr. Tycho Van Aller, of Schenectady, New York, to whom had been awarded the Edward Longstreth Medal of Merit for his Calorizing Process. The President presented the medal and accompanying documents to Mr. Van Aller, who thanked the Institute for the honor conferred upon him.

The paper of the evening on "Oil Shales" was presented by Mr. Dean E. Winchester, Geologist, United States Geological Survey, Grand Valley, Colorado. An outline was given of the characteristics, distribution and value of the oil shales of the United States, together with a discussion of the origin of the oil that may be distilled from the shale. The methods of mining shales were described, as well as the various foreign and domestic processes for the extraction of the oil. Mention was also made of some of the by-products of this industry. A summary of the attempts now being made to develop a commercial oil shale industry was also given.

On motion of Mr. Franklin, duly seconded, the thanks of the meeting were extended to the speaker for his interesting paper.

Adjourned.

George A. Hoadley,
Secretary pro tem.

STANDING COMMITTEES, 1919,

OF THE BOARD.

ELECTION AND RESIGNATION.

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W. C. L. Eglin,
Alfred W. Gibbs,
George R. Henderson,
George D. Rosengarten.

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Harry F. Keller,
Edward V. McCaffrey,
James S. Rogers.

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Harry F. Keller, Chairman,
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Charles Day,
Robert W. Lesley,
Louis E. Levy.

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Coleman Sellers, Jr., Chairman,
G. H. Clamer,
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Nathan Hayward,
William Chattin Wetherill.

EXHIBITIONS.

Francis T. Chambers, Chairman,
Theobald F. Clark,
Benjamin Franklin,
Charles A. Hexamer,
Marshall S. Morgan.

PUBLICATIONS.

Louis E. Levy, Chairman,
W. C. L. Eglin,
George A. Hoadley,
George D. Rosengarten,
E. H. Sanborn.

STOCKS AND FINANCE.

Walton Forstall, Chairman,
Cyrus Borgner,
Alfred C. Harrison,
James S. Rogers,
E. H. Sanborn.

OF THE INSTITUTE.

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Clarence A. Hall,
George A. Hoadley,
Harry F. Keller,
Henry Leffmann,
Marshall S. Morgan,
Paul Spencer,
George F. Stradling,
W. C. Wetherill.

COMMITTEE ON MEETINGS.

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Charles Baskerville,
G. H. Clamer,
A. S. Cushman,
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Fred H. Colvin,
Henry F. Colvin,
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Geo. A. Hoadley,
Henry Howson,
A. E. Outerbridge, Jr.
Coleman Sellers, Jr.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, February 5, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 5, 1919.

DR. H. JERMAIN CREIGHTON *in the Chair.*

Mr. Benjamin Franklin was unanimously elected Chairman for the year 1919.

The following report was presented for final action:

No. 2727: Stabilized-Platform Weighing Scale. Mr. Frederick J. Schlink appeared before the Committee and explained the construction of the scale. Edward Longstreth Medal of Merit to Frederick J. Schlink, of Washington, D. C., adopted.

R. B. OWENS,
Secretary.

SECTIONS.

Section of Physics and Chemistry.—A meeting of the Section and the Philadelphia Section of the Illuminating Engineering Society was held in the Hall of the Institute on Thursday evening, February 6, 1919, at 8 o'clock, with Dr. George A. Hoadley in the chair. The minutes of the previous meeting were read and approved.

C. E. Clewell, Assistant Professor of Electrical Engineering in the University of Pennsylvania, presented a communication on "Industrial Lighting." Modern industrial lighting was discussed, with special consideration of its physical and psychological aspects, and of its relation to industrial management, accident prevention, and wartime problems. Attention was paid to existing codes of factory lighting and their effective administration. The lecture was illustrated with lantern slides. A vote of thanks was extended to Professor Clewell. After some remarks by Doctor Hoadley, the meeting adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, February 19, 1919.)

RESIDENT.

MR. GEORGE W. LEWIS, Mechanical Engineer, 16 Princeton Avenue, Swarthmore, Pennsylvania.

MR. GEORGE SATTERTHWAITE, Manufacturer of Steel, in care of Tacony Steel Company, Tacony, Philadelphia, Pennsylvania.

MR. CLINTON F. SNYDER, Chemist, 1633 Locust Street, Philadelphia, Pennsylvania.

DR. F. E. STEWART, in charge of Pure Food Department, H. K. Mulford Company, Philadelphia, Pennsylvania.

NON-RESIDENT.

Mr. Howard L. Adams, Managing Director, Keystone Institute, Reading, Pennsylvania.

Mr. Frederick J. Blatz, Leather Manufacturer, P. O. Box 967, Wilmington, Delaware.

Dr. E. Leon Chaffee, Assistant Professor of Physics, Cruft Laboratory, Cambridge, Massachusetts.

Mr. D. B. Heilman, Mechanical, Electrical and Chemical Engineer, Reading, Pennsylvania.

Mr. Roy Linden Hill, Chemist, 619 East Broad Street, Tamaqua, Pennsylvania.

Mr. Robert E. Horton, Consulting Hydraulic Engineer, 57 North Pine Avenue, Albany, New York.

Mr. Edmund G. Robinson, Chemist, 1618 Broome Street, Wilmington, Delaware.

Mr. L. T. Sherwood, Chemist, in care of du Pont Dye Works, Wilmington, Delaware.

Mr. Charles F. Sulzner, Retired, 630 Fourteenth Street, Miami, Florida.

CHANGES OF ADDRESS.

Mr. Gordon M. Atherholt, in care of Atlantic Refining Company, Philadelphia, Pennsylvania.

Mr. Walter Atlee, 1404 Massachusetts Avenue, N. W., Washington, District of Columbia.

Mr. C. H. Berry, 18 Washington Avenue, Detroit, Michigan.

Lt. Comm. A. W. K. Billings, Apartado 570, Barcelona, Spain.

Mr. Frederick C. Fearing, 1614 Pennsylvania Building, Philadelphia, Pennsylvania.

Lieut. A. H. Gfrorer, in care of Lakewood Engineering Company, Cleveland, Ohio.

Mr. J. P. Jefferson, R. F. D. No. 1, Santa Barbara, California.

Dr. Enoch Karrer, Bureau of Standards, Washington, District of Columbia.

Mr. Luther D. Lovekin, Mill Creek Road, Ardmore, Pennsylvania.

Mr. John C. Parker, in care of Lefax, Inc., Sheridan Building, Philadelphia, Pennsylvania.

Mr. A. T. Smith, in care of The Permutit Company, 440 Fourth Avenue, New York, New York.

Dr. Leslie D. Smith, 5019 Walnut Street, Philadelphia, Pa.

Mr. Ernest Stutz, 828 Stratford Avenue, South Pasadena, California.

Mr. R. John Titzel, 571 Lemon Street, Lancaster, Pennsylvania.

Mr. Francis R. Wadleigh, 24 Broad Street, New York, New York.

Major R. A. Widdicombe, P. O. Box 1821, Washington, District of Columbia.

NECROLOGY.

Dr. Walter Victor Turner.—Dr. Walter Victor Turner, Manager of Engineering of the Westinghouse Air Brake Company, died at the Columbia Hospital, Wilkinsburg, Penna., Thursday morning, January 9, 1919, after a

WALTER V. TURNER
1866–1919

comparatively brief illness, due to a severe and sustained attack of Bright's disease. In the death of Doctor Turner the world has lost the greatest air brake expert of the age. Doctor Turner had a unique career. His work stands preëminent in its contribution to the safety of train movement and the development of transportation capacity in the way of longer trains, and higher speeds for both freight and passenger trains.

Doctor Turner was born in Epping Forest, Essex County, England, April 3, 1866. He engaged in the woollen textile business of that country, and came to America in 1888 to investigate the business of wool-growing in the West for the corporation with which he was associated. In 1893 he was made secretary and manager of the Lake Ranch Cattle Company, Raton, New Mexico. The venture flourished, and a little later he entered, with a partner, upon a similar business of his own. But in 1897, because of changed business conditions, this ended unsuccessfully. While still on the ranch a wrecked freight train had supplied him with a triple valve, which he appropriated and carried to his home, where, by candle light, his evenings were spent in exploring the mechanisms, passageways and functions of the valve, and he mastered its intricacies by inspection alone, without instruction.

He was then obliged to seek a position with the Atchison, Topeka and Santa Fé Railway as a car repairer, a position quite modest as compared with his previous one, but, because of its connection with railroading, one toward which he felt a strong attraction. The lure of the railroad appealed to his latent mechanical genius, giving promise of sure development into greater and higher usefulness. He advanced rapidly, becoming in one month gang foreman, and not long afterwards, chief car inspector. His work in the car department of the railroad naturally brought him into intimate contact with the air brake, which he was quick to recognize as an exceptionally ingenious and invaluable mechanism. The air brake enticed him, and he began an extensive study of its several parts.

He rapidly gained a reputation for proficiency in air brakes, and was placed in charge of the air brake instruction car on the Santa Fé road. From general air brake instructor he was promoted to mechanical instructor for the entire system, during this time having taken out twenty-two air brake patents.

In 1903 he entered the employ of the Westinghouse Air Brake Company as mechanical expert, applying himself to the betterment of existing apparatus and to improved devices with which to meet rapidly changing conditions of the times then occurring in both steam road and electric railway fields.

His advancement in his new work was consistent and rapid. He passed quickly through subordinate official positions and in 1907 was made Mechanical Engineer; in 1910, Chief Engineer; in 1915, Assistant Manager, and in 1916, Manager of Engineering.

One of his great achievements was the development of the K triple valve, of which there are now over two millions in use. This valve overcame many troubles incident to long freight train operation. Where before the operation of fifty freight cars per train with standard valves was considered the maximum by railways, the improvements embodied in the K valve made possible the air brake handling of freight trains from 100 to 125 cars per train. This, in turn, made possible greater traffic, heavier locomotives and higher capacity cars.

By his untiring energy and ingenuity, the braking of trains has been highly developed and perfected. Passenger trains which formerly required nearly 2000 feet to be stopped from a speed of sixty miles per hour, now stop in half that distance. On modern elevated and subway trains, the electro-pneumatic brake is stopping trains in a still shorter distance in proportion to speeds run. The most recently built New York subway has air brake equipment on its cars giving braking power automatically regulated by the entrance and exit of passengers to and from the car, and suitably changing the braking power of the car as the load carried reduces and increases. Thus a constant braking effect is provided regardless of the varying load carried by the car. These various electro-pneumatic brake devices have speeded up train service on all the subways and elevated roads where used. The empty and load brake he developed and perfected for freight service has greatly enlarged the traffic capacity of mountainous roads in permitting the safe operation of long and heavy freight trains on steep grades, and has improved the level road operation of trains of mixed loads. His great, continuing and ever-realized ambition was to make it possible to run two trains where but one could run before. In short, his contribution to the transportation industry of the world will always be an outstanding feature of its history.

He possessed a keen sense of differences, of essentials and degree. His marvelous knowledge of details and their proper proportion enabled him to lead the technical man and the less informed man with equal facility through the intricate maze of air brake problems.

He was a keen and liberal contributor of writings, lectures and discussion to scientific engineering and railway organizations and was the author of many books and papers regarded as air brake classics. Among the most notable of these is the paper he presented before The Franklin Institute in April, 1916, on "The Vital Relation Between Train Control and the Value of Steam and Electric Railway Properties."

He was awarded by The Franklin Institute the Edward Longstreth Medal of Medit in December, 1910, at the time he presented his paper on "The Air Brake as Related to Progress in Locomotion." As a recognition of his air brake inventions and developments he was awarded the Elliott Cresson Gold Medal by The Franklin Institute in May, 1912. He was made a fellow of the Royal Society of Arts of London in May, 1915, and as a further recognition of his achievements the degree of Doctor of Engineering was conferred on him by the University of Pittsburgh in May, 1918.

He was a member of the American Society of Mechanical Engineers, numerous social organizations, and practically all of the railway associations of this country.

He became a member of The Franklin Institute in November, 1910.

Mr. J. Sellers Bancroft, 917 Pine Street, Philadelphia, Pennsylvania.

Mr. Louis E. Levy, 1424 North Fifteenth Street, Philadelphia, Pennsylvania.

Mr. A. A. Robinson, 900 Tyler Street, Topeka, Kansas.

Mr. Raymond W. Tunnell, 15 North Fifth Street, Philadelphia, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

American Concrete Institute.—Proceedings, vol. 14. 1918.
American Society for Testing Materials.—Proceedings, vol. 18. 1918.
BULLENS, D. K.—Steel and Its Heat Treatment. 1918.
International Catalogue of Scientific Literature. 5 vols. 1918.
JONES, F. D.—Mechanisms and Mechanical Movements. 1918.
MASON, W. P.—Water Supply. Considered Principally from a Sanitary Standpoint. 1916.
Mineral Industry.—Vol. 26. 1917.
Poor's Manual of Public Utilities.—Vol. 6. 1918.
Royal Society of Edinburgh. Transactions.—Vol. 52, pt. 1. 1918.
STEINHEIL, ADOLPH, and VOIT, ERNEST.—Applied Optics; The Computation of Optical Systems. 1918.
Thomas' Register of American Manufactures.—Vol. 10. 1919.
VILLAMIL, R. DE.—Resistance of Air, 1917.

BOOK NOTICES.

U. S. TARIFF COMMISSION, "DYES AND OTHER COAL-TAR CHEMICALS." Report to Congress Recommending Amendments to Title V of Act of September 8, 1916. 83 pages, 8vo. Washington, Government Printing Office, 1918.

This is a report to Congress by the Tariff Commission concerning changes that in the opinion of the Commission should be made in the division of the Act of September 8, 1916, technically termed "Title V." The changes are numerous and too complicated to be considered in the space here available, but those who are interested in the details of the tariff problem will be able by reading this pamphlet to see that the question involves as many conflicting interests as that of the League of Nations.

HENRY LEFFMANN.

THE NEW SCIENCE OF THE FUNDAMENTAL PHYSICS. By W. W. Strong, B.S., Ph.D., 107 pages, and table of contents, no index. Mechanicsburg, Pa., S. I. E. M. Company, 1918. Price, $1.25.

This is a profound study of the principles of physical science and is well worth perusal by those who are interested in that rapidly developing and complex field. It is certainly "caviare to the general." We are not informed whether the author is teaching science, nor the meaning of the mysterious initials indicating the publisher, but to the physicist the text will not be less attractive by reason of the lack of information on these points. Even the Preface shows a departure from conventionalities, for it is dated "March 8–June 7, 1918." It is probably not to be assumed that the author took all this time to write it, but that this is the period devoted to the whole book. The work contains a good deal of recondite science mixed with some recondite theology and ethics. The following extracts from the last paragraph of the Preface and the last paragraph in the book, respectively, will serve to examplify these features:

"Events appear to hold the promise that the concentrated effort of peoples to win in a war will be replaced by a more unified aim to know life and nature and to apply this knowledge more fully to the service of man."

"It (the vision that nature has given us) brings us into a deep harmony with the Great Intelligence and we see in the way our efforts have rewarded us the measure of our image of Him and that it is the duty of man and of all his organizations to be blessed by the fullest communion and harmony with the Divine Plan." (A slight typographical error in the original has been corrected in this quoting.)

The latter sentence is part of the essay on the Relativity Theory. This theory is very abstruse and it is given to few to comprehend it. The reviewer is not one of these favored few, but he confesses that while he has gained some information from reading the chapter on relativity, he has read this closing sentence several times and cannot make anything of it.

HENRY LEFFMANN.

THE J. E. ALDRED LECTURES ON ENGINEERING PRACTICE, 1917–1918. The Johns Hopkins University, Department of Engineering. 236 pages, illustrations, 8vo. Baltimore, The Johns Hopkins Press, 1918. Price, $1.00.

These lectures are the second series given for the undergraduates of the University by the gift of Mr. J. E. Aldred. They deal with the practical phases of engineering work and are designed to lead the student to an appreciation of the methods of professional practice. The following representative subjects are covered: Steam-Electric Power Plant Design; The Relation Between Civil and Military Engineering; The Development of Concrete Road Construction; Copper Refining; The Coal Problem; The Growth of Electric Systems; The Control of Stream Pollution; The Manufacture of Structural Steel.

A periodic contact of this kind with important engineering projects should prove a material aid in giving the student a clear conception of the ends towards which his studies are being applied.

LUCIEN E. PICOLET.

A HANDBOOK OF COLLOIDAL-CHEMISTRY. By Dr. Wolfgang Ostwald. Second English edition, translated from the third German edition by Dr. Martin H. Fischer, of the University of Cincinnati, with numerous notes added by Emil Hatschek, of the Cass Institute, London. 271 pages, contents and index, and 63 illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $3.50 net.

The value of this work can be best exhibited by an extract from the preface to this edition: "Yielding to pressure from the publishers, who find need at this time for a new printing of this volume, we have reluctantly met their request to revise and bring up to date the original translation, as made by one of us with the assistance of Ralph E. Osper and Louis Berman. . . . We have met the situation by leaving untouched those large portions of the volume which contain the author's individual views." It is evident that the work fills satisfactorily a great need in chemistry in this country and England, and it is very sad to think of the developments which have compelled competent translators to make the apology which is easily detected in the above quotation. "Quis talia fando Myrmidonum, Dolopumve aut duri miles Ulyssei temperet a lacrimis."

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

A Handbook of Colloid-Chemistry: The Recognition of Colloids, the Theory of Colloids, and Their General Physico-Chemical Properties, by Dr. Wolfgang Ostwald. Second English edition, translated from the third German edition, by Dr. Martin H. Fischer, with numerous notes added by Emil Hatschek. 284 pages, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, no date.

Screw Threads: Bibliography of Available Material on the Systems and Classification of Screw Threads, Including Tolerances, Allowances and Symbols of Nomenclature; and on Gauges, Methods of Testing, and Specifications Prepared at the Request of U.S. Screw Thread Commission and Arranged in Alphabetical Order According to Authors and Titles, and With an Index by Henry E. Haferkorn. Supplement No. 2, Professional Memoirs, November–December, 1918. 62 pages, 8vo. Washington Barracks, D. C., Engineer School, 1918.

U. S. Bureau of Mines: Bulletin 170. Extinguishing and Preventing Oil and Gas Fires, by C. P. Bowie. 50 pages, illustrations, plates, 8vo. Technical paper 152. The Inflammability of Aluminum Dust, by Alan Leighton. 15 pages, 8vo. Technical paper 196. Notes on the Black Sand Deposits of Southern Oregon and Northern California, by R. R. Hornor. 42 pages, illustrations, plates, maps, 8vo. Washington, Government Printing Office, 1918.

United States Tariff Commission: Second Annual Report, Fiscal Year ended June 30, 1918. 118 pages, 8vo. Washington, Government Printing Office, 1919.

U. S. Coast and Geodetic Survey: Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Vieques, P. R., 1915 and 1916, by Daniel L. Hazard. 100 pages, plates, quarto. Results of Observations Made at the United States Coast and Geodetic Survey Magnetic Observatory at Cheltenham, Md., 1915 and 1916. Washington, Government Printing Office, 1918.

U. S. House of Representatives: In Matter of Investigation of Packing Industry. Testimony of J. Ogden Armour on Behalf of Armour & Company, Jan. 21, 1919, Before Committee on Interstate and Foreign Commerce. 68 pages.

U. S. Reclamation Service: Work and Homes for Our Fighting Men. 24 pages, illustrations, 8vo. Washington, Government Printing Office, 1919.

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HOW THE NITROGEN PROBLEM HAS BEEN SOLVED.*

BY

HENRY JERMAIN MAUDE CREIGHTON,
Department of Chemistry, Swarthmore College. Member of the Institute.

INTRODUCTION.

THE enormous quantities of nitric acid and ammonia employed in the chemical industries and the nitrates used in agriculture were, until recently, obtained solely from the nitrate deposits in Chili, and from the destructive distillation of coal, these being the chief sources of inorganic nitrogen compounds. The world's total production of ammonia, calculated as ammonium sulphate, is one and one-half million tons per annum, while the present annual production of sodium nitrate is 3,120,000 tons.

In view of the ever-increasing demand for Chili saltpetre, some years ago estimates were made of the probable life of the Chilian deposits, and while these estimates vary considerably, it is evident that in a relatively short time the deposits will be exhausted. In addition to the nitrate beds in Chili, other deposits have been found in California, southeastern Oregon and in the Argentine, but the amount is either not very large or the deposits are situated in localities not easily accessible.

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* Communicated by Professor Creighton.

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For some time there has been recognized the necessity of obtaining inorganic nitrogen compounds from other sources than those mentioned above. This necessity has been emphasized by the recent war. Attention naturally turned to the atmosphere, which has been estimated to contain four quadrillion tons of nitrogen, or twenty million tons over every square mile of the earth's surface. Unfortunately, however, before this inexhaustible supply of nitrogen can be used for industrial or agricultural purposes, it must first be converted into nitric acid, nitrates or ammonium compounds, forms in which nitrogen is most readily utilized.

During the past few years, much important research has been carried out on the transformation of atmospheric nitrogen into these forms—on the fixation of atmospheric nitrogen—and owing to the very fruitful results that have attended these labors, the practical solution of the nitrogen problem may be considered achieved. These investigations have led to the development of five different methods which may be broadly classed as follows:

I. The direct oxidation of nitrogen to its oxides with subsequent formation of nitric acid or nitrates, as exemplified in the Arc Processes;
II. The direct combination of nitrogen with hydrogen to form ammonia, as typified by the Haber Process;
III. The absorption of nitrogen by carbides, as developed in the Cyanamide Process;
IV. The absorption of nitrogen by metals in the form of nitrides, as represented by the Serpek Process;
V. The conversion of nitrogen into cyanides, as set forth in the Bucher Process.

At the present time the first three of these methods are successfully operated on a commercial basis. While, as yet, the Bucher process has scarcely passed beyond the experimental stage, it has been claimed that if the mechanical difficulties can be solved, ammonia will be produced more cheaply by this process than by either the Haber or Cyanamide processes.

The importance of these methods of nitrogen fixation in times of war, when the supply of Chili saltpetre may be cut off, is shown by the fact that Germany in 1914 produced 60,000 tons of nitric acid, in 1916, 300,000 tons and in 1917, 320,000 tons, from atmospheric nitrogen.

I. ARC PROCESSES.

OUTLINE OF THE PRINCIPLES UNDERLYING THE FORMATION OF NITRIC ACID FROM ATMOSPHERIC NITROGEN.

The conversion of atmospheric nitrogen into nitric acid is made up of several steps, which may be expressed by the following equations:

$$(1)\quad N_2 + O_2 \rightleftarrows 2NO;$$

$$(2)\quad 2NO + O_2 \rightleftarrows 2NO_2;$$

$$(3)\quad 2NO_2 + H_2O \rightleftarrows HNO_3 + HNO_2.$$

Since, in the presence of oxygen, nitrous acid is rapidly oxidized to nitric acid, we may write:

$$(4)\quad 4NO_2 + O_2 + 2H_2O \qquad 4HNO_3.$$

If instead of treating nitrogen peroxide with water, it is brought into contact with an aqueous solution of an alkali, nitrates and nitrites are formed.

The transformation of atmospheric nitrogen to nitric acid is by no means as simple as might appear from the above equations. The oxidation of nitric oxide to nitrogen peroxide is a reversible change: above 140° C., the latter commences to decompose into nitric oxide and oxygen, and this dissociation increases with rise in temperature until, at 620° C., it is practically complete. Therefore, between these two temperatures, the gas mixture consists of nitric oxide, nitrogen peroxide, oxygen and nitrogen (from the air). Since an equimolar mixture of the two oxides of nitrogen behaves towards aqueous solutions of alkali as if it were pure nitrogen trioxide, it is possible under proper conditions with these two gases to produce practically pure nitrite, in accordance with the equation:

$$(5)\quad N_2O_3 + 2NaOH = 2NaNO_2 + H_2O.$$

Many difficulties have been encountered in the oxidation of atmospheric nitrogen to nitric oxide. It has been found extremely difficult to obtain profitable yields of the oxide on passing an electric discharge through air, owing to the fact that the reaction expressed by equation (1) is reversible, and that, at even moderately high temperatures, the position of equilibrium is such that only small quantities of the oxide are formed. Since the formation of nitric oxide from its elements is an highly endothermic reaction (at ordinary temperature the formation of two moles of nitric oxide is accompanied by the absorption of 43,200 gramme-calories), it follows in accordance with Le Chatelier's law that with rise in temperature the position of the equilibrium of the reaction will be displaced in the direction which favors the formation of the oxide. Starting with a given nitrogen-oxygen mixture, the concentration of nitric oxide present at equilibrium will be greater the higher the temperature. From a study of the reaction at lower temperatures, the concentrations of nitric oxide which would be present in the equilibrium mixture at higher temperatures have been calculated, and the values thus obtained have been found to be in good agreement with those determined by experiment, as shown by the data contained in Table I.

TABLE I.

Temperature ° C.	Volume per cent. of NO in equilibrium mixture.	
	Observed.	Calculated.
1538	0.37	0.35
1604	0.42	0.43
1760	0.64	0.67
1922	0.97	0.98
2307	2.05	2.02
2402	2.23	2.35
2627	....	3.18
2927	....	4.39

The close agreement between the two sets of values in Table I is a strong argument in favor of the reaction being a purely thermal one, although evidence has been brought forward which supports the view that temperature is not the only factor which influences the reaction.

Since the velocity of all chemical reactions increases with temperature, it is evident that in order to produce nitric oxide successfully from nitrogen and oxygen, it will be necessary to work, not only at a temperature at which an appreciable amount is formed, but also at a temperature at which its formation takes place rapidly. The influence of temperature on the velocity of the formation of nitric oxide is illustrated by the data contained in Table II.

The values in the last column of Table II show that while at even as high a temperature as 1227° C. the rate of formation of nitric oxide from its constituents is so slow as to be negligible, it is produced instantaneously at temperatures above 2227° C. On the other hand, the times required for the *decomposition* of one-half of a given quantity of nitric oxide are 7.35×10^3 minutes at 627° C., 5.80×10^2 minutes at 827° C., 3.30 minutes at 1227° C., and 1.21×10^{-3} minutes at 1827° C. It is evident from these figures that at temperatures below 827° C. the rate of decomposition of nitric oxide into its constituents is so slow as to be negligible in practice.

From the preceding data, it is obvious that a very high temperature is essential for the formation of nitric oxide in even moderately small quantities. The most convenient means of producing this high temperature is the electric arc, and this is the only method which thus far has met with success. Moreover, although it has been assumed that the efficacy of the electric arc is due to its high temperature, still the observations of a number of investigators indicate the probability of purely electrical influences playing a part in the formation of nitric oxide in the electric discharge.

TABLE II.

Temperature ° C.	Time required for the formation of one-half the theoretical nitric oxide concentration at atmospheric pressure.	
	Minutes.	
1227	1.81×10^3	(1.26 days)
1427	5.90×10	
1627	2.08	
1827	8.43×10^{-2}	(5.06 seconds)
2027	3.75×10^{-3}	
2227	1.77×10^{-4}	(0.01 second)
2427	8.75×10^{-5}	
2627	5.75×10^{-6}	(0.000035 second)
2827	3.10×10^{-8}	

At any rate, whatever be the action of the arc, even under the most favorable conditions only a few per cent. of nitric oxide is produced when equilibrium sets in. Consequently, in order to convert large quantities of nitrogen and oxygen into nitric oxide, it is necessary to remove the latter from the sphere of the action of the arc as fast as it is formed. In this way the attainment of equilibrium is prevented and the process becomes continuous. Since, as has just been pointed out, the rate of decomposition of nitric oxide into its constituents is very rapid at high temperatures, and negligibly slow for all practical purposes at temperatures below 827° C., it is necessary to quickly and efficiently cool the gas mixture after removing it from the action of the arc, in order to preserve a high concentration of the oxide. The more rapid the cooling, the less the decomposition of the oxide formed at the high temperature of the arc. An idea of the temperature of the gas mixture in the arc may be gained from the fact that, with high tension arcs, concentrations of nitric oxide as high as eight volume per cent. have been obtained. This concentration corresponds to a temperature of 3700° C.

Many investigations have been carried out for the purpose of increasing the concentration of the nitric oxide formed in the arc, and it has been found that this is influenced by the rate of flow of the nitrogen and oxygen through the arc, and by the proportion of these elements in the initial gas mixture. Thus Grau and Russ, using high tension arcs, found that with a high velocity of flow of the gases through the arc the concentration of nitric oxide formed was small, while with diminishing velocity the concentration increased. These investigators found, when operating at 2300–2600 volts and 175 watts, that the nitric oxide concentration produced was 2.90 volume per cent. when the flow of air through the arc was 104.1 liters per hour, and 4.181 volume per cent. when the flow was reduced to 30.9 liters per hour. The equilibrium concentration of nitric oxide in the arc was calculated by extrapolation for zero velocity. This gave 5.5 volume per cent. from air, and 6.6 volume per cent. from a mixture containing equal volumes of nitrogen and oxygen, these quantities being independent of the length of the arc. The nitric oxide concentration may also be increased by allowing the air after passing through the arc to mix with the unarced gas. It has been suggested that these conditions are favorable to the formation of ozone, and that it is the oxidation of the nitrogen by the ozone that brings about an increase in the oxide concentration.

After the formation of nitric oxide in the arc, the next step in the production of nitric acid is its oxidation to nitrogen peroxide. This may be brought about by the oxygen contained in the air which escaped combustion in the arc. Since nitrogen peroxide, as already pointed out, commences to break up into nitric oxide and oxygen at 140° C., and is completely dissociated at or above 640° C., it is evident that until the temperature of the gas mixture, after removal from the arc, falls below the latter temperature, no peroxide will be formed; and until the temperature is reduced below 140° C., the gas mixture will contain both oxides of nitrogen. If the cooled gas mixture is passed into water the nitrogen peroxide is converted into nitric and nitrous acids, in accordance with the reaction expressed in equation (3). As the nitrous acid readily changes into nitric acid:

$$(5) \quad 3HNO_2 \rightleftharpoons HNO_3 + 2NO + H_2O,$$

the total reaction may be expressed by the equation:

$$(6) \quad 3NO_2 + H_2O \rightleftharpoons 2HNO_3 + NO.$$

Since the reactions expressed by equations (3) and (5) are reversible, the equilibrium of the latter and, therefore, that of the former is distributed by the subsequent oxidation of the nitric oxide liberated in (5), *i. e.*,

$$(7) \quad 2NO + O_2 \rightleftharpoons 2NO_2.$$

and, consequently, a given quantity of nitrogen peroxide must be ultimately transformed into nitric acid.

When a mixture of nitrogen peroxide and oxygen is led into water, nitric acid is formed rapidly until its concentration reaches about 40 per cent.; the absorption then gradually becomes slower until a concentration of 50 per cent. is attained, above which the rate of absorption rapidly diminishes. The concentrations of nitric acid obtained at ordinary temperatures from gas mixtures containing different quantities of nitrogen peroxide are as follows:

Concentration of Nitrogen peroxide.	Limiting Concentration of nitric acid obtained.
Volume per cent.	Per cent.
1	ca 46
2	ca 52
5	55

Since, technically, the cooled gases from the arc usually contain from 1–2 per cent. of nitrogen peroxide, it should be possible to produce aqueous nitric acid having a concentration of about 50 per cent. by treating the gas mixture with water. If, as previously mentioned, the hot gas mixture, containing both nitric oxide and nitrogen peroxide, is treated with an aqueous alkali solution, the nitrate and the nitrite of the alkali metal will be formed, the latter predominating the higher the temperature at which absorption takes place.

A few figures regarding the consumption of electrical energy in the production of nitric acid by the arc process may be of interest. Haber has calculated that the theoretical yield of nitric acid is 134 grammes per kilowatt hour or 1174 kilogrammes per kilowatt year, at 4200° C., and 93.5 grammes per kilowatt hour or 819 kilogrammes per kilowatt year at 3200° C. While the yield of acid is smaller at the lower temperature, it must be remembered that in practice there is a smaller loss of nitric oxide due to decomposition during the period of cooling, and a smaller loss of heat by radiation. Technical yields of nitric acid are always less than those indicated by the above figures.

On account of the small yields of nitric acid in the arc process, cheap power must be available in order to produce the acid profitably by the method that has been outlined; and it is chiefly in Norway and the Alpine countries, where there are large quantities of cheap water power that, up to the present, atmospheric nitrogen has been converted into nitric acid on a commercially successful scale by the arc process. Assuming that one kilogramme of combined nitrogen has a market value of twenty-five cents, then on the basis of electric power at the rate of $10 per kilowatt year, a technical yield of 60 grammes of nitric acid per kilowatt hour pays for the power three times over. The variation in the cost of water power in a number of different localities is shown by the data[1] given in Table III (the asterisk denotes prices at which the power is actually sold).

TABLE III.

Locality.	Total costs or charges per kilowatt year to large consumers.
Niagara*	$22.40–$26.60
Niagara (Ontario Power Co. to Municipalities)*	$13.60
Sault Ste. Marie *	$13.30
Cameron Rapids, Ontario	$11.00
Kootenay Power Co	$32.00
Kanawa Falls, Virginia	$12.80
Svaelgfos, Norway	$ 2.64
Notodden, Norway	$ 4.33
Sweden	$4.16–$9.60
Austria (Meran)*	$15.20
Savoy (Bellegrade)*	$14.10
Savoy (Chedde)	$ 5.87

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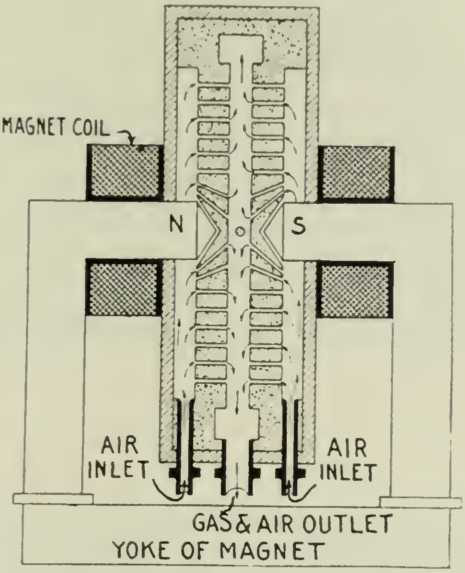
[1] Lucke, C. E., *Electrochem. and Met. Ind.*, 6, 230 (1907).

With respect to the power which is being developed at Muscle Shoals, Tennessee, United States Army engineers have placed the cost between $9 and $12 per kilowatt year or about 1.5 mills per kilowatt hour.

Another source of cheap electrical power is off-peak power, which, it has recently been claimed,[2] can be secured in many places in the United States at a lower cost than Norwegian power.

FIG. 1.



BIRKELAND-EYDE FURNACE.

TECHNICAL FURNACES FOR THE PRODUCTION OF NITRIC OXIDE FROM AIR.

Of the different furnaces that have been devised for the oxidation of nitrogen in the electric arc, only a few have been successful. Of the latter the most important are the Birkeland-Eyde furnace, which is used in Norway, France and Spain; the Schönherr furnace, which is employed in Norway and Germany; and the Pauling furnace, which is operated in Italy, Austria and Germany. In addition to these, the Moscicki and the Kilburn Scott furnaces should be mentioned.

(a) *The Birkeland-Eyde Furnace.*

The Birkeland-Eyde furnace, a vertical section of which is shown in Fig. 1, has the appearance of a large cylinder resting on its side between the poles of a huge electro magnet (Fig. 2). This cylinder is made of two similar halves of heavy cast iron plates (Fig. 3), which are bolted together. The interior of the furnace is lined with refractory material perforated with numerous small openings through which the air enters the narrow, circular reaction chamber situated in the centre. A peripheral channel in the casting of the furnace serves to carry away the nitrous gases from the reaction chamber. The large terminal poles of the electro magnet are bevelled and are imbedded in the lining of the furnace. The coils of the magnet, placed immediately outside of the iron shell, are fed by a direct current and absorb 0.35 to 1 per cent. of the total furnace load. The thick, water-cooled tubular, copper electrodes, supported on ball insulators, enter the reaction chamber through opposite sides of the furnace, their internal ends being separated by a distance of one centimetre. The cooling effect of the electrodes causes a loss of only about 7.5 per cent. of the electrical energy.

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[2] Steinmetz, C. P., *et al.*, Proc. Am. Inst. Elec. Eng. (1918). Advance copy.

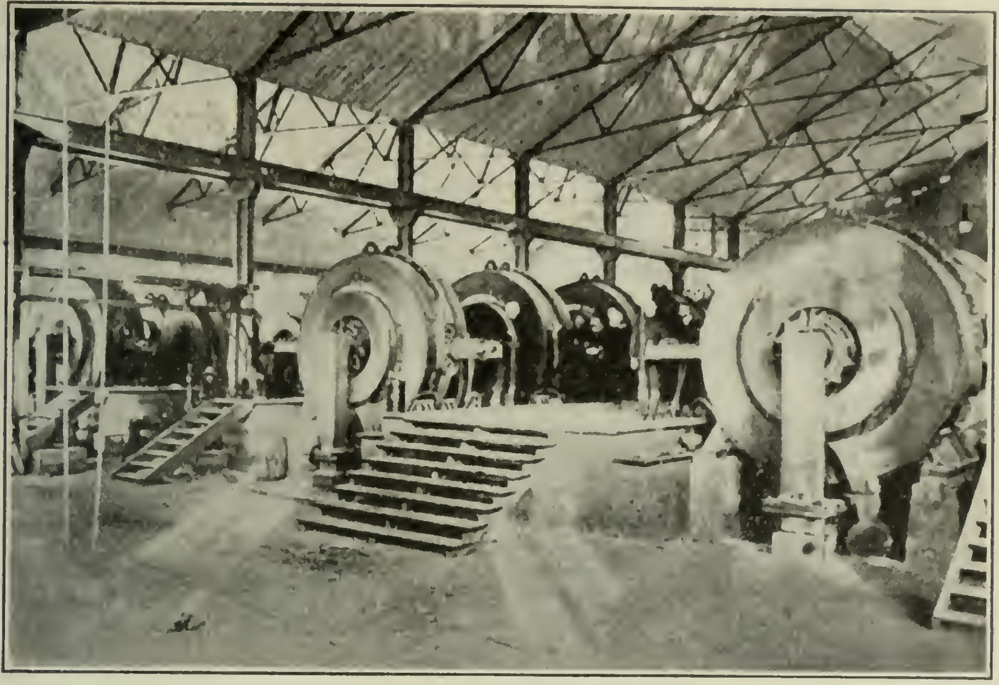
The positions of the electrodes and the poles of the magnet are such that the magnetic field is perpendicular to that of the arc. The arc is maintained by an alternating current of about 5000 volts and 50 periods per second, and is forced by the magnetic field into two semi-circular discs of flame (Fig. 4) which alternately rise and break in the lower and upper half of the reaction chamber, producing what appears to be a thin, circular sheet of flame 1.8 metres in diameter that burns with great steadiness.

The air on entering the reaction chamber impinges on the flame at right angles, where it is partially oxidized to nitric oxide. Notwithstanding the very high temperature of the arc (over 3000° C.), that of the nitrous gases on leaving the reaction chamber is between 800° C. and 1000° C., while the temperature of the refractory lining seldom exceeds 700° C., due to the cooling effect of the air current.

The capacity of the Birkeland-Eyde furnace has increased from 300 kilowatts in 1906 to 4000 kilowatts at the present time.

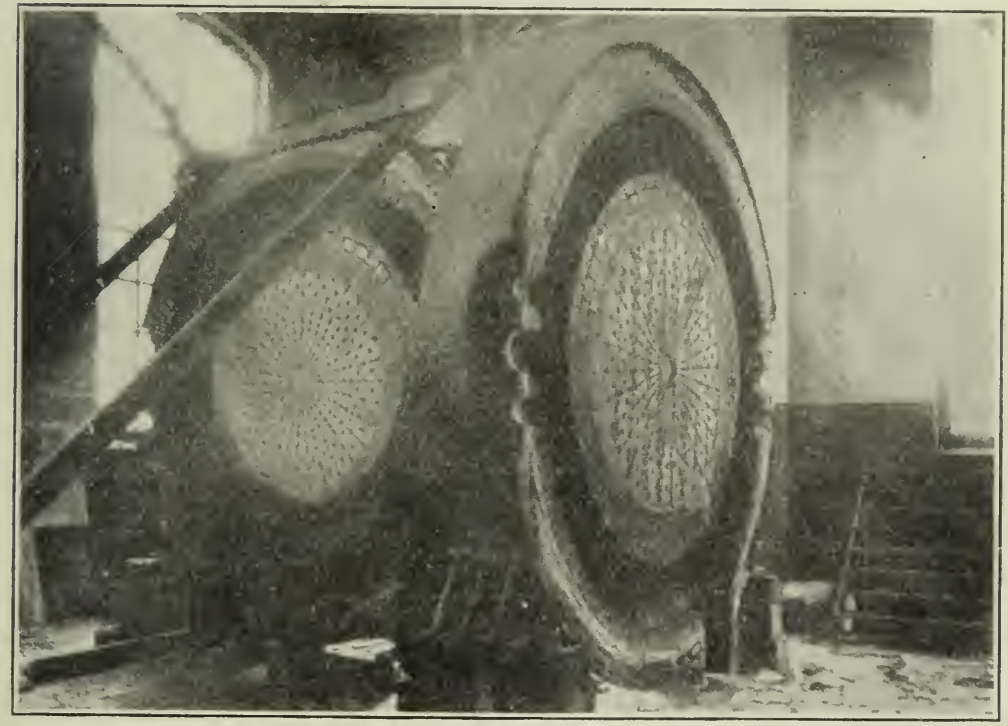
The most striking features of this furnace are its simplicity and durability. It burns for weeks with scarcely any regulation. It is only necessary to change the electrodes every three or four weeks and the refractory lining every four to six months. A few workmen are able to operate a large number of these furnaces.

FIG. 2.



BIRKELAND-EYDE FURNACES AT NOTODDEN, NORWAY.

FIG. 3.

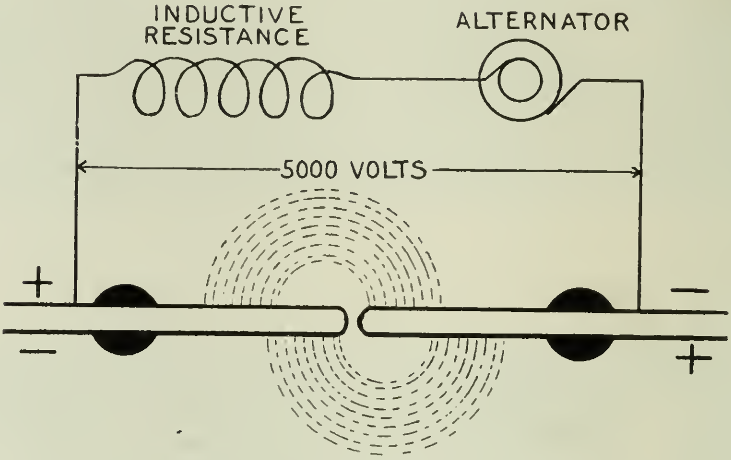


BIRKELAND-EYDE FURNACE.

(*b*) *The Schönherr Furnace.*

This furnace differs in principle from the one just described, in that, in place of the circular sheet of flame, a long, slender arc is developed in the narrow axis of an iron tube, through which a current of air is forced. The arc is stabilized by imparting a whirling motion to the air. In this furnace the air passes along and surrounds the arc with which it is in contact for an appreciable time, whereas in the Birkeland-Eyde and Pauling (described below) furnaces the air, entering at right angles to the electric discharge, is in contact with the arc for an exceedingly short time.

FIG. 4

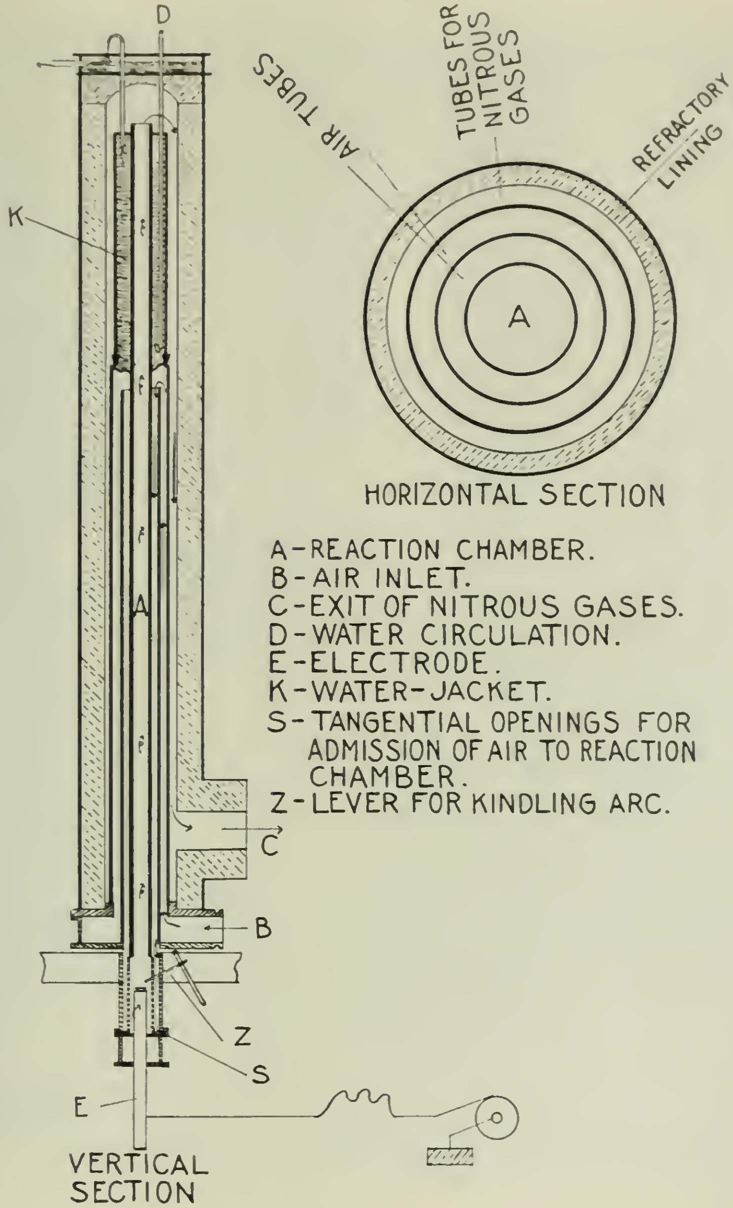


DIAGRAMMATICAL REPRESENTATION OF THE DISPLACEMENT OF THE SEMICIRCULAR ARCS IN BIRKELAND-EYDE FURNACE.

The Schönherr furnace, cross-sections of which are shown in Fig. 5, consists of a vertical cylinder of iron plate, 23 feet in height, lined with refractory material. In the centre are placed three concentric wrought iron tubes. The inner tube, A, is six inches or less in diameter and constitutes the reaction chamber. The other tubes form passages through which the air enters and through which the nitrous gases pass from the reaction chamber after being in contact with the arc. By means of this arrangement, a large portion of the heat of the out-going gases is transferred to the in-coming air. The path traversed by the gases is indicated by the arrows in Fig. 5.

The air enters the reaction chamber through a number of tangential openings so arranged at its base that there is imparted to it a pronounced vortical motion. This motion is sufficiently strong to maintain a material difference in pressure between the

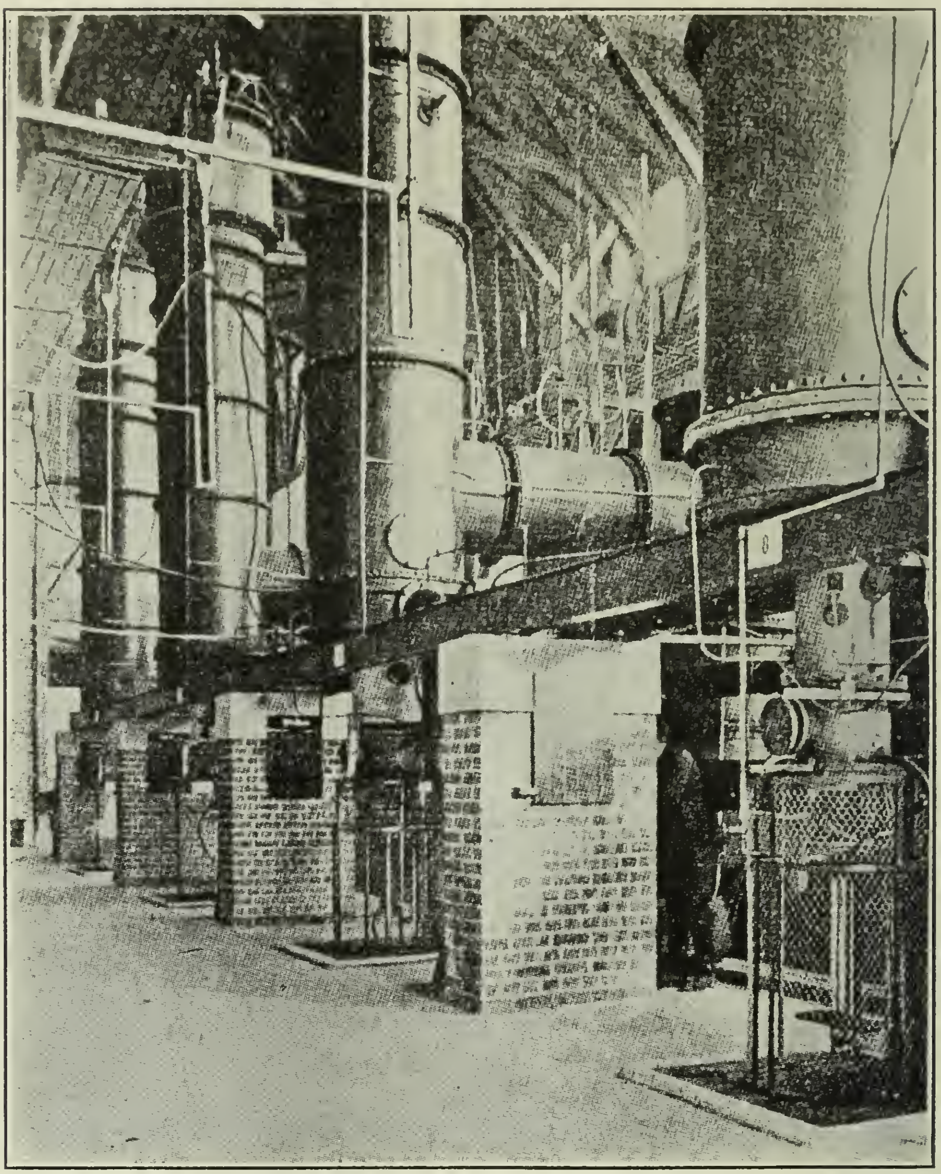
FIG. 5.



SCHÖNHERR FURNACE.

axis of the vortex occupied by the arc, and the outer sections of the air current. The admission of the air to the reaction chamber is controlled by a lever. The upper third of the reaction chamber is surrounded by a water jacket, K. The nitrous gases leave the reaction chamber at a temperature of about 1200° C., and on passing through the furnace transmit to the in-coming air sufficient heat to raise its temperature to about 500° C.

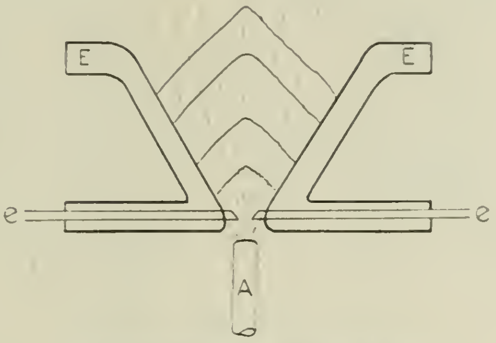
FIG. 6.



SCHÖNHERR FURNACES AT KRISTIANSAND.

An iron bar, E, situated at the lower end of the reaction chamber, serves as the main electrode. This bar is movable in a vertical direction through an opening in the hollow, water-cooled, copper terminal of the electric current. This electrode projects a little above the surface of the terminal, and is so arranged that it can be moved upwards by a cog mechanism as it is worn away by the action of the arc. The rate of wear is about twenty millimetres daily. The reaction chamber, in direct connection with the other metallic parts of the furnace, serves as the second electrode. The lever Z is used to start the arc, which when once kindled is rapidly drawn upwards by the air current, the vortical motion of which maintains a slender, rod-like flame which occupies the axis of the reaction chamber throughout its length. The flame only comes in with the reaction chamber at its upper extremity which is cooled by the top portion of the water-jacket, K.

FIG. 7.



ELECTRODES OF PAULING FURNACE.

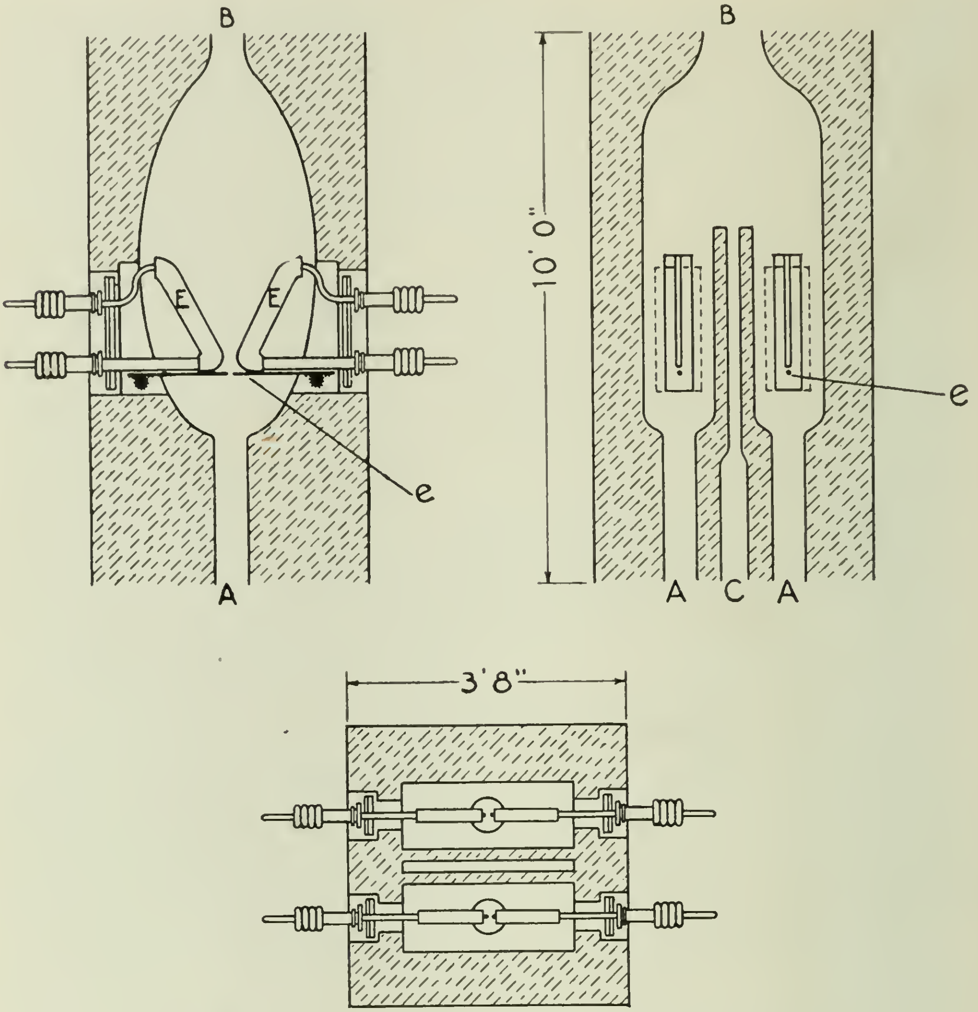
Owing to the fact that the length of the reaction chamber is governed by the voltage, and also that there is a limit to the current that can be dealt with by a single electrode, the capacity of the Schönherr furnace is restricted to 1000 kilowatts (Fig. 6).

The Schönherr furnace requires considerable attention, on account of the frequency with which the arc is extinguished, rekindling having to be done by hand.

(c) *The Pauling Furnace.*

In the Pauling furnace the arc is formed between hollow, water-cooled electrodes, E (Fig. 7), set at an angle of about 80°, and which, at their lowest point, are slightly over one and one-half inches apart, so as not to interfere with the air blast from the supply pipe, A. Very thin kindling blades, *e*, passing through the curved part of the main electrodes, are employed to start the arc which is maintained with a high tension alternating current. As soon as the arc is formed, it is forced by the air blast from A upwards along the inclined electrodes. At each half period a new arc is kindled, so that, with rapid alternations of the current, a sheet of flame is produced which fills the space between the electrodes and projects above them, often attaining a height of three feet.

FIG. 8.

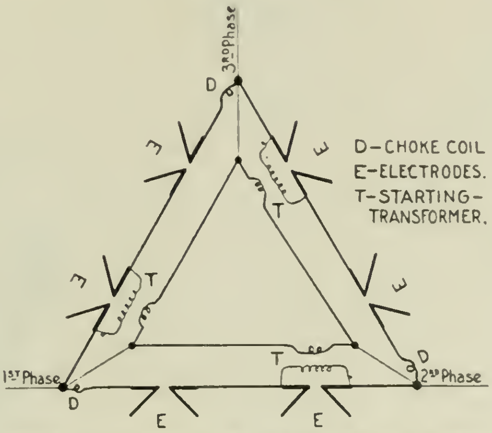


VERTICAL AND HORIZONTAL SECTIONS OF THE PAULING FURNACE.

The wrought-iron, refractory-lined furnace (Fig. 8), which is rectangular in shape with a cross section of 3.8 × 4 feet and a height of 10 feet, contains two sets of electrodes arranged in series. Air enters beneath each set of electrodes through the inlets A, while the nitrous gases leave through the common outlet B. A portion of the nitrous gases from the furnace is switched off and returned through the hollow dividing wall C, after being cooled down to the proper temperature. This gas enters the upper portion of the furnace where it rapidly cools the nitrous gases from the arcs without diluting them.

One furnace with two arcs in series is placed in each leg of a three-phase current supply. Since a much higher E. M. F. is required for kindling an arc than for its maintenance when once kindled, a transformer (T, Fig. 9) producing an ancillary current of high E. M. F., but of low power, is connected across one pair of electrodes of each series. The high tension coil of this transformer gives an E. M. F. which is several times greater than that of the main supply, so that the current which is shunted through the primary induces a voltage sufficiently high to kindle the arc. By means of an ingenious switching device the ancillary current comes into play when high tension is required for kindling the arcs, but is shut off when the main circuit is completed through the sheets of electric flame which develop between the furnace electrodes. If an arc is accidentally extinguished, the secondary current is automatically switched on.

FIG. 9.



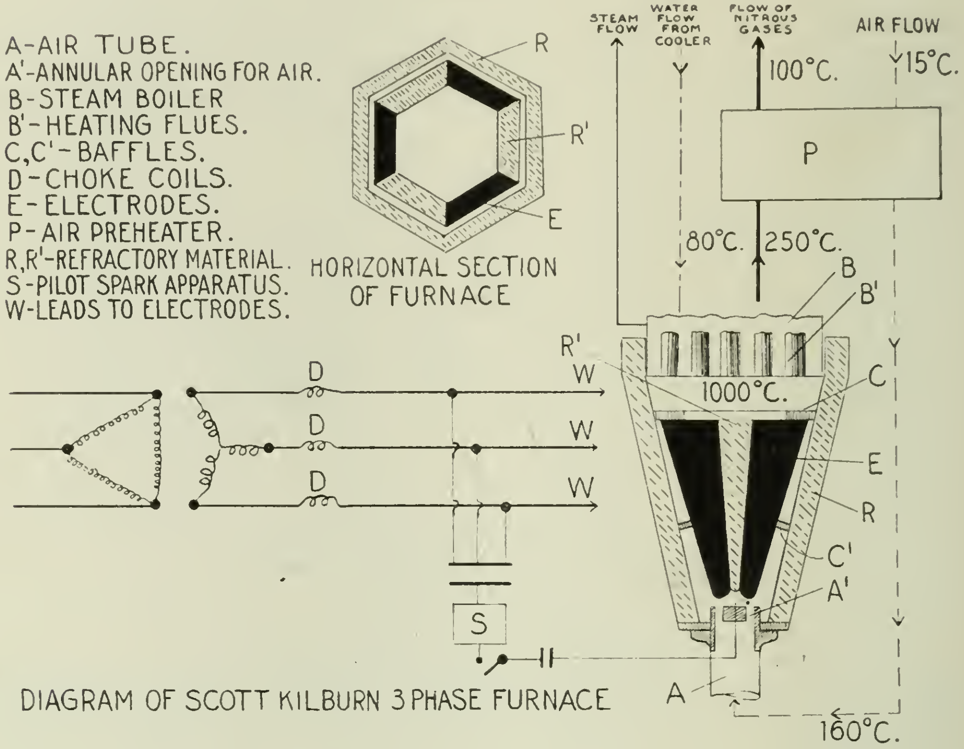
PAULING ELECTRODES IN SERIES ON EACH PHASE.

(*d*) *The Kilburn Scott Furnace.*

Before concluding the consideration of different types of arc furnaces, a brief description should be included of the Kilburn Scott furnace, as it has the advantages of simplicity, conservation of heat, low first and maintenance costs, and a relatively good yield of nitric oxide.

This furnace, which is shown diagramatically in Fig. 10, employs three wedge-shaped electrodes, E, spaced 120° apart, having their sides inclined towards each other 30° from the vertical, and arranged with intervening refractory material, R′, so as to form a six-sided conical space with the apex at the bottom. Each electrode is connected through inductance to one leg of a 2000 volt three-phase circuit.

FIG. 10.



The air enters the bottom of the furnace directly beneath the electrodes through the annular opening A, and is prevented from escaping without passing through the arc by the baffles, C and C′. With a three-phase current of 60 periods, a combined arc consisting of 360 separate flames per second is flared out by the air current into what appears as a double cone having one apex at the bottom and the other at the top. High frequency "pilot" sparks from the apparatus S serve to break down the dielectric resistance and allow the main current to arc between the electrodes.

A tubular boiler, B, with heating flues, B′, placed directly above the arc and through which the nitrous gases from the furnace pass, cools these gases from about 1000° C. to 250° C. and utilizes the waste heat.

THE CONVERSION OF NITRIC OXIDE TO NITRIC ACID, ETC.

The following outline of the method of the conversion of the nitric oxide formed in the arc furnace into nitric acid, nitrates and nitrites is illustrated by the diagram shown in Fig. 11.

Air is forced by a powerful blower into a large iron pipe line which conveys it to the furnace, where it is partially oxidized to nitric oxide. The nitrous gases, which leave the furnace at a temperature of somewhat over 1000° C., are then carried by a refractory-lined iron main to a tubular steam boiler, in which the gases during their passage through the heating flues have their temperature reduced to 200° C.–250° C. The steam produced in this boiler is utilized for operating evaporating kettles, running the engines which compress the air to work the pumps, etc. By the use of a turbo-generator in conjunction with the steam boiler, 10–15 per cent. of the energy consumed in the furnace can be regenerated. The boiler may either form a part of the furnace, as in the Kilburn Scott process, or it may be separate, as in the Norwegian installations. It is important that the feed water of the boiler should be sufficiently hot to prevent moisture being deposited on the tubes, and this is readily accomplished by employing water from the cooling tank and also that which is used to cool the electrodes, thus giving a further saving of heat.

From the steam boiler the nitrous gases pass on to a cooling tank, where their temperature is further reduced to about 50° C. This tank consists of a large number of aluminum tubes over which cold water flows and through which the gases pass.

On leaving the cooler the gases are led to an oxidation tank. This is a large iron cylinder lined with acid-proof stone. Here the gases are allowed to remain in gentle motion for a short time, in order that the nitric oxide may be oxidized to nitrogen peroxide, the air which accompanies the gases from the furnace containing sufficient oxygen for this purpose. The extent of oxidation depends upon the length of time the gases are allowed to remain in the tank, 12 seconds being required for 50 per cent.

and 100 seconds for 90 per cent. oxidation of a furnace gas containing 2 per cent. of nitric oxide.

Blowers force the gases from the oxidation chamber through an aluminum pipe-line to the absorption towers. These towers are made of granite or iron and are filled with broken quartz, which is acted upon by neither the nitrous gases nor the nitric acid. At the Birkeland-Eyde plants, in Norway, these towers are 65.62 feet high and 18 feet in diameter. In these plants a series of three granite towers for the formation of acid followed by one of two iron towers for the formation of nitrite is usually employed. Centrifugal aluminum fans assist the passage of the gases through the towers.

FIG. 11.

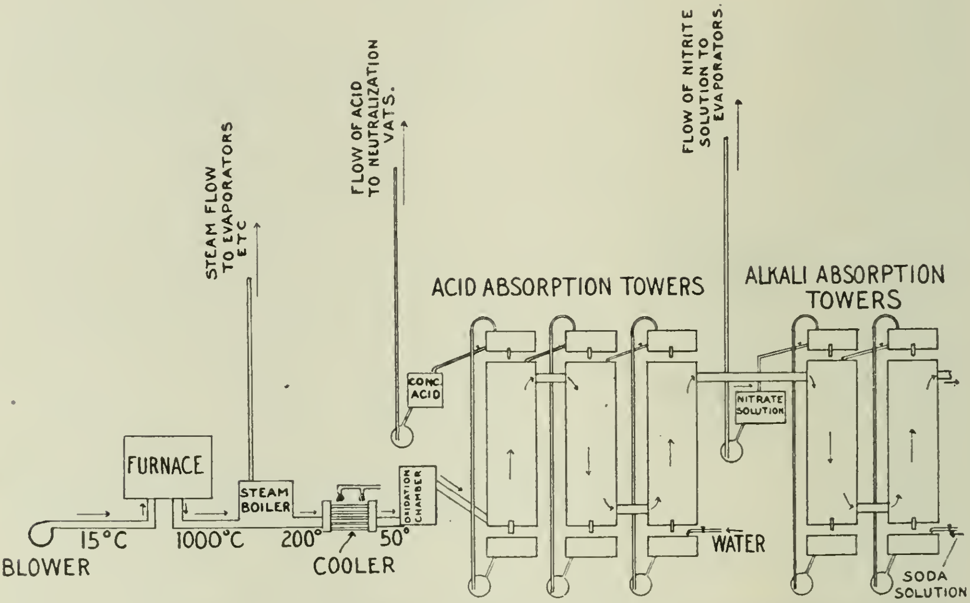


DIAGRAM OF APPARATUS FOR CONVERSION OF NITRIC OXIDE TO NITRIC ACID ETC.

The gases enter the first tower at the bottom, pass upwards, and thence are led by an earthen-ware pipe to the top of the second tower, down through which they pass and then through a second earthen-ware pipe are conducted to the bottom of the third tower. From the top of this tower they are conveyed to the first of the two iron towers. Water trickling down through the quartz in the third tower is gradually converted into dilute nitric acid which is received in a cistern at the bottom. The arrangement of the absorbing system is such that the liquid can be pumped up and passed repeatedly through the same tower, or used to percolate the preceding tower and so be brought in contact with a higher nitrogen peroxide concentration. After the absorbing liquid is pumped to the reservoirs at the top of the towers, it is automatically distributed in jets by earthen-ware pipes. When the acid concentration of the percolating liquid has attained a concentration of about 33 per cent., it is pumped to naturalization vats and converted into calcium nitrate or ammonium nitrate, or the dilute acid is further concentrated in the usual way.

Since on leaving the third tower the gases still contain upwards of 20 per cent. of the original nitric oxide concentration, they are passed through the two iron towers percolated by a solution of caustic soda, in which absorption is more rapid and complete than in water. Of the entire quantity of nitrous gases passed through the five towers, about 97 per cent. is absorbed. By regulating the time the nitrous gases are allowed to remain in the oxidation tank, the proportions of nitric oxide and nitrogen peroxide in the gas which comes from the third tower can be made such that practically pure nitrite will be formed in the alkali towers. Sodium nitrite, free from nitrate, can also be produced by leading the nitrous gases directly to the second set of towers when their temperature has been reduced to 250° C., since at this temperature the two oxides of nitrogen are present in the gas mixture in equimolar proportions.

At Rjukan II, in Norway, the distance between the furnaces and the absorption towers is about 3000 feet.

POWER, CURRENT SUPPLIES, YIELDS, ETC.

Of the different electrical processes for the fixation of atmospheric nitrogen, only the arc process is capable of intermittent operation with off-peak power. Arc furnaces, therefore, may be installed wherever cheap three-phase power is available for sixteen to twenty hours per day. It is not even necessary to install special generating machinery, as the ordinary standard voltages of 5500 and 6600 and periodicities of 25 and 60 are suitable.

A factory of convenient size for the fixation of atmospheric nitrogen is one which has a capacity of about 10,000 kilowatts, but in larger factories the cost per kilowatt, the operation cost, and the overhead charges per unit of finished product, are relatively lower.

The current supplies required for the first three furnaces that have been described are as follows:

The Birkeland-Eyde Furnace.—Direct current for the magnetic field of 4500 lines of force per square centimetre.

Alternating current of 5000 volts and 50 periods for furnaces having a capacity of 600–4000 kilowatts.

The Schönherr Furnace.—Alternating current of 4200 volts and 50 periods for furnaces having a capacity of 600–1000 kilowatts.

The Pauling Furnace.—Single-phase alternating current of 4000–6000 volts and 50 periods for furnaces having a capacity of 400–1000 kilowatts.

The average yield of nitric acid in the Birkeland-Eyde furnace is between 500 and 600 kilogrammes per kilowatt year, although with some furnaces it has run as high as 950 kilogrammes. In the Schönherr and the Pauling furnaces it amounts to 675 kilogrammes and 525 kilogrammes, respectively, per kilowatt year.

The production of nitric acid and nitrates from atmospheric nitrogen by the arc processes has made rapid strides in Norway, increasing from about 1000 tons in 1905 to an annual output of upwards of 100,000 tons at the present time. The Norwegian installations are located at Notodden and other parts of the Telemark district in southern Norway, where abundant water power is available at a very low cost. By constructing a dam a short distance below Lake Mös, a reservoir was created with a storage capacity of 190 thousand million gallons, thereby ensuring a constant water supply for two of the largest power stations.

ADVANTAGES AND DISADVANTAGES OF THE ARC PROCESSES.

The advantages of the arc processes may be summarized as follows:

1. Cheapest cost of nitric acid (not of fixed nitrogen) if power can be obtained for $13 per kilowatt year or less, and efficiently utilized in a large plant run continuously to capacity.

2. Efficient intermittent operation is possible with off-peak power.

3. The steam required for the concentration of the nitric acid and other purposes may be produced from the large amount of waste heat.

4. Direct production of nitric acid without intermediate products.

5. Free raw materials.

6. Labor requirements are small.

The following are the chief disadvantages of the arc processes:

1. Large power requirements per ton of nitric acid.

2. Greater dilution of nitric acid when first produced than by other processes.

3. High installation charges for both power and plant.

4. Difficulties involved in the transportation of nitric acid.

II. THE DIRECT COMBINATION OF HYDROGEN WITH NITROGEN.

OUTLINE OF THE UNDERLYING PRINCIPLES.

It has long been known that under certain conditions small traces of ammonia can be formed in a mixture of hydrogen and nitrogen, but it is due to the brilliant pioneer work of Haber and the subsequent development of his methods by the Badische Anilin and Soda Fabrik, that the production of ammonia from its constituents on a successfully commercial scale has been achieved. However, notwithstanding the fact that over a million tons per annum of synthetic ammonium sulphate are produced by the company just referred to, but very meagre details regarding the process are available.

The reaction between hydrogen and nitrogen leads to an equilibrium according to the equation:

$$N_2+3H_2 \rightleftarrows 2NH_3. \tag{8}$$

This equilibrium is represented by the expression:

$$K=\frac{p_{NH_3}}{p_{N_2}^{\frac{1}{2}} \cdot p_{H_2}^{\frac{3}{2}}}, \tag{9}$$

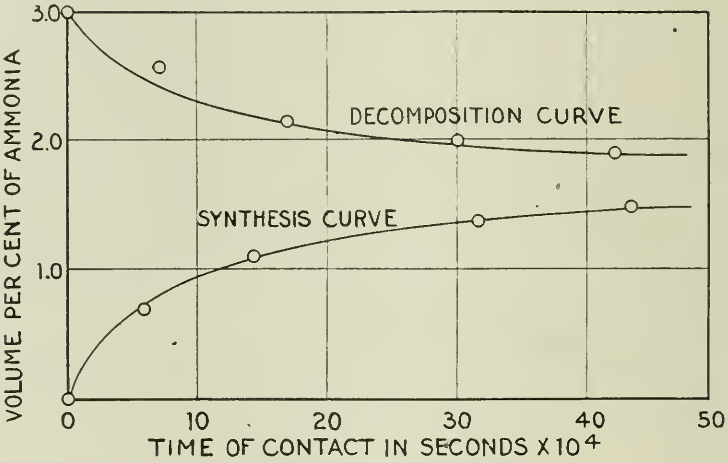
where p represents the partial pressures of the respective gases at equilibrium and K is the equilibrium constant. If in (9) there is substituted for the partial pressure the product of the total pressure, P, and the fraction, C, which each gas forms of the total volume at equilibrium, the equation takes the form:

$$P.\ K=\frac{C_{NH_3}}{C_{N_2}^{\frac{1}{2}} \cdot C_{H_2}^{\frac{3}{2}}}. \tag{10}$$

The formation of ammonia from hydrogen and nitrogen is an exothermic reaction, and at ordinary temperatures it is accompanied by an evolution of 11,890 gramme-calories per mole of ammonia. It follows, consequently, in accordance with Le Chatelier's law, that the concentration of ammonia present in the gas mixture at equilibrium must diminish as the temperature at which the reaction takes place is increased. In order, therefore, to obtain a high concentration of ammonia, the temperature must be kept as low as possible. Unfortunately, on the other hand, a high temperature is necessary to obtain a favorable velocity of reaction.

The thermal synthesis of ammonia has been studied recently by Maxted[3] by passing mixtures of hydrogen and nitrogen through a small arc contained in a capillary tube. His investigations showed, as is illustrated graphically in Fig. 12, that at a temperature of about 3000° C. the amount of ammonia present in the gas mixture after passing through the arc increased with the time the hydrogen-nitrogen mixture remained in contact with the arc. Since the "synthesis curve" indicated that, under the conditions employed, the ammonia concentration at equilibrium is between 1.5 and 2 per cent. by volume, hydrogen-nitrogen mixtures containing 3 per cent. of ammonia were passed through the arc. As is shown by the "decomposition curve" in Fig. 12, the ammonia concentration being above its equilibrium value sank instead of rising after contact with the arc. This second curve shows that the equilibrium concentration of ammonia is about 1.7 per cent. at atmospheric pressure under the conditions studied. Maxted has also plotted out approximately the complete experi-

FIG. 12.



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[3] Maxted, E. B., *J. Soc. Chem. Ind.*, 37, 232 (1918).

mental ammonia curve up to a temperature of 3000 °C. This curve is shown in Fig. 13.

As it is evident from equation (10) that, for a given temperature, the ammonia concentration at equilibrium will be higher the greater the pressure at which the reaction is carried out, the best conditions for the formation of ammonia from its constituents are, therefore, a high pressure and a low temperature. But as the velocity with which equilibrium is attained under the latter condition is extremely slow, it is accelerated by employing a catalyst. By means of suitable catalysts, it is possible to attain equilibrium rapidly and to produce satisfactory concentrations of ammonia at pressures between 150 and 200 atmospheres at 500° C. to 600° C. But even with the most active catalysts at present known, it is difficult to obtain satisfactory results below the former temperature. On the other hand, it is unnecessary to operate at temperatures over 700° C., for with a gas mixture containing one volume of nitrogen to three volumes of hydrogen the maximum concentration of ammonia is rapidly attained below this temperature. With this gas mixture the equilibrium concentration of ammonia decreases with rise in temperature at a constant pressure, and for a given temperature increases with the pressure, as is illustrated by the data given in Table IV.

FIG. 13.

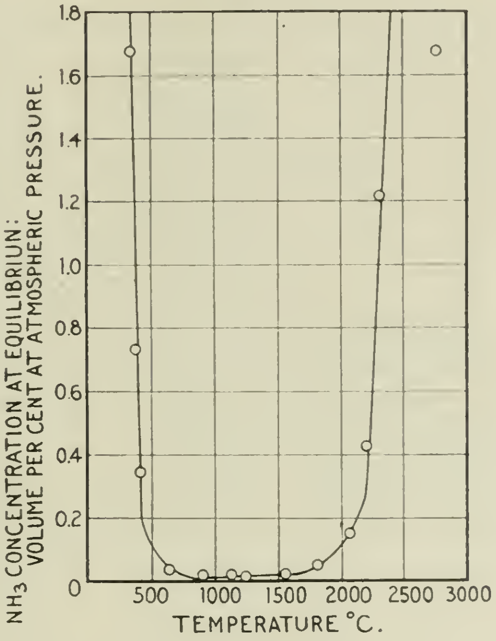


TABLE IV.

Temperature ° C.	Equilibrium concentration of ammonia at pressures of:		
	1 atmosphere.	100 atmospheres.	200 atmospheres.
400	0.48	......	....
500	0.13	10.7	18.1
550	......	7.0	12.2
600	0.048	4.5	8.3
650	......	3.0	5.8
700	0.021	2.1	4.1
750	0.0159	1.54	2.99
800	0.011	1.1	....
850	0.0089	0.874	1.68
950	0.0055	0.542	1.07
1000	0.0032	......	....

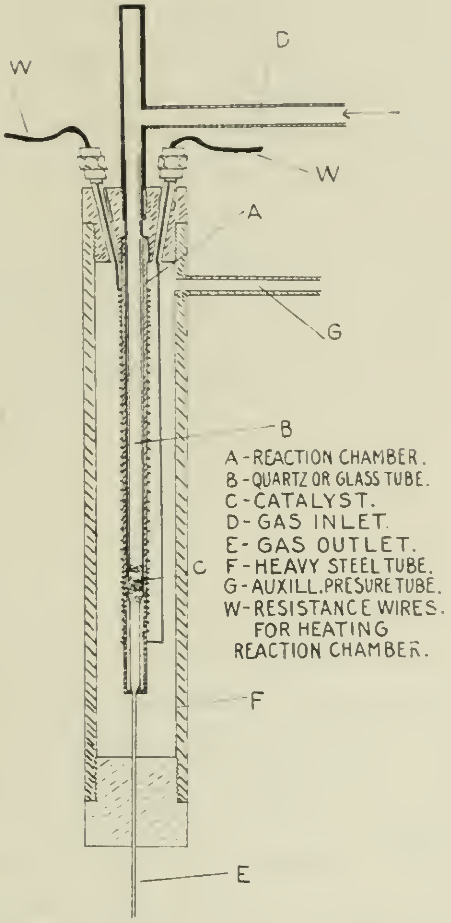
THE TECHNICAL SYNTHESIS OF AMMONIA.

The essential principles of the Haber furnace are shown diagrammatically in Fig. 14. The reaction chamber consists of a thin wrought iron or steel tube, A, inside of which is contained a second tube, B, of quartz or glass which is narrowed towards the lower end where the catalyst is contained between asbestos plugs. The tube A is wound on the outside with a heating resistance wire, W. The gas mixture enters the reaction chamber through D and leaves the furnace at the bottom through E. The reaction chamber is enclosed in a much stronger steel tube, F, in which a high pressure is maintained, so as to prevent the hot, thin, steel tube from bursting under its high internal pressure.

Many difficulties have been encountered in the construction of the Haber furnace so as to maintain pressures of over 150 atmospheres at temperatures of 500° C. to 600° C. At about 400° C. iron loses its solidity to a very extraordinary degree. Steel loses its carbon at the temperatures employed, thus reducing to a minimum its capacity of withstanding pressure. Iron becomes pervious to hydrogen under the high pressures, and its properties change. Further, the wall of the reaction chamber rapidly deteriorates under the influence of the ammonia mixture at high temperatures. While these difficulties have been overcome, the details have been kept secret. Also there is but little information regarding the details of the construction of the furnace and its operation. It is known that the process is not without danger, as very small amounts of oxygen or air are sufficient to cause explosion at high pressures, but this danger is guarded against by having the apparatus in bomb-proof chambers.

Since the electrical method of heating is attended with many difficulties, a system has been adopted in Germany in which a sufficient quantity of air is introduced into the catalyst chamber, in such a manner that the proper reaction temperature is maintained by internal combustion. While this method of heating simplifies the construction of the furnace, it is liable to give rise to explosions owing to the incomplete combustion of the air.

FIG. 14.



VERTICAL SECTION OF A HABER FURNACE

The hydrogen-nitrogen mixture is forced through the furnace at such a velocity that an ammonia concentration of about 8 per cent. is maintained. On leaving the furnace, the gases pass through a refrigerating system where the ammonia is liquefied, while the hydrogen and nitrogen are returned to the reaction chamber and are again passed over the catalyst. Since in the reaction the first portions of ammonia are formed more rapidly than successive increments, it is desirable to remove the ammonia as completely as possible before returning the residual gases to the reaction chamber. The maximum temperature that can be employed in the refrigerating system depends upon both the ammonia concentration and the pressure of the gas mixture. In Table V is recorded the theoretical percentage of ammonia left in a gas under two different pressures after passing through a refrigerating system at the designated temperatures.

Of the various catalysts investigated for accelerating the velocity of the synthetic formation of ammonia, by far the most effective is osmium, but, unfortunately, the world's supply of this metal does not amount to much over 200 pounds, and the annual production is very small. Next in order comes uranium, which, in the form of the carbide, crumbles under high pressures to a fine powder possessing at 500° C. a very high catalytic activity. In using this catalyst, it is essential that no water be present in the gases. Besides these two metals, iron, tungsten, molybdium, molybdic acid, ammonium molybdate and manganese are good catalysts for this reaction. The catalytic activity of tungsten depends in a large measure upon the manner in which it is prepared. It is worthy of note that platinum, although very closely related to osmium, possesses but a very slight catalytic activity.

TABLE V.

Temperature ° C.	Per cent. of ammonia remaining in the residual gas mixture when the pressure is:	
	150 atmospheres.	200 atmospheres.
0	2.7	2.1
−10	1.9	1.4
−20	1.2	0.9
−30	0.76	0.57
−40	0.47	0.35
−50	0.25	0.19
−60	0.13	0.1

Certain foreign substances—" promoters "—have been found to increase the activity of the catalyst. The most effective of these are the oxides and hydroxides of the alkali metals and of the metals of the alkali earths. For example, an iron-potash catalyst is particularly active. In many cases just a minute quantity of the promoter is sufficient to increase the catalytic activity.

As is so often the case with catalysts, those employed in the synthesis of ammonia are very susceptible to poisoning. Thus, sulphur, selenium, tellurium, phosphorus, arsenic, boron or their hydrides, as well as lead, bismuth, tin, and many organic compounds behave as poisons. Extremely minute quantities of oxygen-sulphur compounds, which are almost always present in the so-called pure gases of commerce, suffice to render the catalyst either absolutely inactive or to diminish its activity very considerably. Iron prepared from its oxide containing 0.01 per cent. sodium sulphate or 0.1 per cent. sulphur is quite useless as a catalyst. Recognition of these facts necessitates the preparation of the catalyst free from such poisons, as well as very careful preparation of the gases employed in the reaction. Since as little as one part of sulphur in a million in the gas mixture can be injurious, even electrolytic hydrogen must be further purified.

TABLE VI.

Time of contact with catalyst in seconds.	Percentage of ammonia formed.	Yield of ammonia in kilograms per hour per liter of catalyst space.
0.34	0.65	2.7
0.56	0.94	2.3
1.8	1.8	1.4
3.6	3.2	1.25
7.2	4.7	0.91
10.8	5.1	0.65
24.5	6.8	0.38

The time of contact between the gas mixture and the catalyst influences the amount of ammonia formed. This is illustrated by Table VI, which gives both the percentage and yield of ammonia produced at 550° C. and a pressure of 150 atmospheres in the presence of an iron-potash catalyst.

The data in Table VI show that for a catalyst chamber of given size the highest yield of ammonia is obtained when the time of contact and the percentage of ammonia formed are both small. However, since any decrease in the percentage of ammonia formed involves an increase in the number of circulations of the gas mixture through the reaction chamber and the delivery of a greater quantity of heat to the refrigerating system, the most economical condition for the synthesis is not a maximum yield of ammonia per hour, but an optimum rate of circulation of the gases.

The variation in the percentage and yield of ammonia with temperature and pressure, employing an iron-potash catalyst and time of contact of 1.8 seconds, is illustrated in Table VII.

It has been found that the best results are obtained when the pressure in the reaction chamber is maintained at 180 atmospheres. Regarding the most suitable working temperature, Maxted [4] points out "it must be borne in mind that, as the synthesis is usually carried out, the percentage of ammonia formed per passage never approaches the equilibrium value for the temperature and pressure used, and thus, within limits, of course, reaction velocity will play an even more important rôle in the determination of the amount of ammonia formed during the time of contact than the absolute value of the equilibrium ammonia percentage. If, on the other hand, the temperature employed be so high that the desired percentage of ammonia unduly approaches the equilibrium percentage, the increase in the reaction velocity due to increased temperature will no longer compensate for the decreased equilibrium ammonia content."

TABLE VII.

Pressure = 150 atmospheres.			Temperature = 550° C.		
Temperature ° C.	Per cent. NH_3	Yield in kg. per hour per liter of catalyst space.	Pressure atmosphere.	Per cent. NH_3	Yield in kg. per hour per liter of catalyst space.
530	1.85	1.55	50	0.55	0.42
			150	1.8	1.4
580	3.57	2.73	180	3.5	2.7

On account of the small and complicated units employed in the Haber process, a large amount of highly skilled labor is required. Further, the technical control of the process is of so great importance and requires such skill that many months are necessary to train a technical staff of experts.

A process which resembles the Haber process has recently been invented in this country by DeJahn of the General Chemical Company, but very little is known regarding its details. One great advantage of this process over that developed by Haber is that the reaction is carried out at a much lower pressure. Ammonia is formed by passing a mixture of hydrogen and nitrogen at 520° C. to 540° C., under a pressure of 80 to 90 atmospheres, over a catalyst formed by igniting a salt of cobalt, manganese, titanium, cerium, boron, uranium or silicon upon a carrier of pumice, and then heating the product (after reduction in hydrogen) with metallic sodium and anhydrous ammonia at 300° C. Satisfactory results have also been obtained with a catalyst made by reducing nickel oxide on pumice with hydrogen at 550° C., adding a small amount of metallic sodium, and heating in anhydrous ammonia to 450° C. With this catalyst 4.5 per cent. by volume of ammonia is obtained under a pressure of 80 to 90 atmospheres at a temperature of 520° C. to 540° C.

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[4] Maxted, E. B., *loc. cit.*

PREPARATION OF HYDROGEN AND NITROGEN.

The preparation and purification of the hydrogen and nitrogen involve one of the chief items of cost in the synthesis of ammonia.

The principal method employed for the preparation of pure nitrogen is the low temperature separation from air. It may also be obtained as a by-product in the manufacture of formic acid from producer gas and sodium hydroxide.

Although a pure hydrogen may be prepared electrolytically, its cost is very high. It may be produced much more cheaply by the alternate action of steam and water gas on iron. However, hydrogen prepared by this method contains 1 to 2 per cent. of carbon monoxide, its presence resulting as follows: During the reducing stage of the process, carbon monoxide decomposes according to the equation,

$$(11) \quad 2CO \rightleftharpoons CO_2 + C,$$

the carbon being deposited on the iron and reacting with the steam subsequently introduced, with the re-formation of carbon monoxide which contaminates the hydrogen. By a modification of the intermittent method, whereby instead of water gas, a gas containing a sufficient concentration of carbon dioxide to prevent the separation of carbon, according to equation (11), is employed for reduction, hydrogen completely free from carbon monoxide and having as high a purity as the electrolytic gas, can be produced with practically no increase in cost. In addition to the methods mentioned, hydrogen may also be obtained as a by-product in the electrolytic manufacture of alkali and in the manufacture of oxalates from formates.

Since the presence of even small traces of impurities in the hydrogen and nitrogen may poison the catalyst, their removal is essential. The methods employed depend on the nature of the impurities, and consist, according to the case, in filtering, washing, conducting over solid absorption agents, and so on. One good method is to bring the gases at high temperature into contact with the material of which the catalyst is prepared, before passing them over the catalyst. This material takes up the impurities, and from time to time is renewed.

PRODUCTION AND COSTS.

The Haber process for the production of synthetic ammonia was installed in Germany in 1913 with a plant capacity of 30,000 tons of ammonium sulphate per annum. This grew to 60,000 tons in 1914; 150,000 tons in 1915; 300,000 tons in 1916; and 500,000 tons in 1917. At the present time ammonia is produced synthetically also in this country and in England. In 1918 the world's production of synthetic ammonia amounted to 140,000 tons.

Ammonia can be produced more cheaply by the synthetic method than by any other. In the Haber process the total energy consumption is given as 1.5 kilowatt hours per kilogramme of nitrogen fixed. Trustworthy information indicates that anhydrous ammonia can be produced in the liquid condition by the Haber process for slightly less than four cents per pound.

ADVANTAGES AND DISADVANTAGES.

The chief advantages of the Haber process for the production of synthetic ammonia are:

1. Cheap ammonia.
2. Anhydrous ammonia in the liquid condition ready for immediate oxidation to nitric acid without purification.
3. Cheap and available raw materials.
4. Possibility of erecting comparatively small plants whenever required.

The following constitute the principal disadvantages:

1. Difficulties involved in the construction of apparatus to withstand high temperatures and high pressures.
2. The highly skilled technical staff required.
3. High repair and renewal costs.

(To be concluded.)

THE VISIBILITY OF AIRPLANES.*†

BY

M. LUCKIESH.

Physicist, Nela Research Laboratory.
National Lamp Works of General Electric Co.

On clear days areas of water are somewhat less conspicuous amid the landscape viewed obliquely than on cloudy and overcast days. That is, the areas on clear days as viewed obliquely are of lower relative brightness than on cloudy and overcast days. This is very noticeable to the eye and is somewhat indicated in Table I. Some small lakes and ponds are strikingly dark amid their surroundings, sometimes appearing almost black. If a pool is clear and deep, with a porous bottom of low reflection-factor, practically the entire brightness is that due to specular reflection from the surface. It has been noted that this is only about 0.02 for a smooth surface of water viewed perpendicularly. Considering this in connection with the data in Tables I and II, it is seen that such a pool would appear very dark.

Values of the brightness of water in terms of that of the zenith sky, both being viewed perpendicularly and simultaneously, as obtained on various days, are presented in the following table:

Table II.

Relative Brightness of Inland Water Viewed Perpendicularly in Terms of Brightness of Zenith Blue Sky.

4:30 P.M.	Sunny day, large clouds	0.58
10:30 A.M.	Clear day	.63
10:00 A.M.	Clear day, some clouds	.80
9:30 A.M.	Clear day, some clouds	.87
2:00 P.M.	Clear day	.99
1:30 P.M.	Clear day, some clouds, high altitude	1.40
1:30 P.M.	Clear day, deep blue sky	.79
	Mean	.87

Some values of the brightness of areas of water viewed at 45 degrees in terms of the brightness of the zenith sky varied from 1.5 to 3.0. The mean of a few values obtained is about 2.2. The brightness was usually much greater at very oblique angles.

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* Based on a paper presented at a meeting of the Section of Physics and Chemistry held Thursday, January 9, 1919.

† Concluded from page 312, Vol. 187, March, 1919.

These values varied considerably at any given time, depending upon the direction of the observation with respect to the sun. The values obtained by viewing a given surface vertically were quite constant over a wide range of sky and weather conditions.

The foregoing measurements of the apparent reflection-factor or the relative brightness of water were made entirely over inland waters such as rivers and the Chesapeake Bay. Such measurements are perhaps generally satisfactory for the purpose in mind; however, inasmuch as such data form the foundation for attaining low visibility for seaplanes similar measurements were made over deep water more than 50 miles from land. A series of measurements were made during an eight-hour flight over Hampton Roads, the Chesapeake Bay, through the Virginia Capes and 50 miles to sea from altitudes varying from 400 to 1200 feet. As in the previous work all measurements were made approximately at normal incidence with the surface of the water. The apparent reflector-factors follow:

Shallow water in Hampton Roads	7.4 per cent.
Deep channel in Chesapeake Bay	4.9 per cent.
Atlantic Ocean 10 to 50 miles from land	3.5 per cent.

The foregoing represent means of many observations. The lowest value obtained for deep water far from land was about 2 per cent., the highest was 5.6 per cent., the most of the values were confined to a range from 3 per cent. to 5 per cent. Of course, the brightness increased for oblique angles and varied with the position of the sun. However, if seaplanes were camouflaged with a dull coat according to the observations made vertically, they would automatically fit into the background fairly well for oblique viewing by appearing brighter at such angles because they cannot be provided with a perfectly matte surface, for the latter cannot be realized in practice. The net result of these observations at sea is to encourage a very dark color for seaplanes. However, it is likely that in many cases we would be concerned with more shallow and more turbid waters nearer shore. In regard to pattern, it does not appear desirable to use more than a slight one if any. This is a matter which may be settled with ease after beginning with the more important data which is available concerning reflection-factor and hue. The difference in hue between shallow turbid water and deep clear water is apparent. The former is a dirty greenish hue for the inland waters studied and the latter is a purer greenish blue.

When these measurements were made far out over the ocean the sky was clear for a portion of the time and then became covered with filmy clouds or a cloud haze; however, the sun was clearly visible. The brightness of the deep water was only 0.3 that of the hazy sky, but the values varied from 0.16 to 1.0. Of course these depend not only upon the depth and clearness of the water but also upon the brightness of the sky, which varies considerably.

From such evidence and other considerations in this report it should be a simple and clear-cut procedure to render seaplanes of the lowest visibility for average conditions as viewed from above. This aspect is discussed in Section 18.

In Fig. 8 it is seen that the water appears of a brightness approximately midway between the brightness of barren land and the brightness of the wooded areas and about equal to that of fields of growing crops. Owing to the fact that the clouds cast very perceptible shadows on the water (Fig. 10) it is evident that most of the brightness of water viewed vertically is due to sunlight diffused throughout it. The brightness of the stream of water in Fig. 8 is seen to be about a mean of the range of brightnesses in the photograph, which coincides with the data in Table I.

TABLE III.

Relative Brighness of Various Types of Areas
(Zenith sky=B).

Woods.	Water.	Fields.	Ploughed or Barren Land.
$0.44B$	$0.53B$	$1.02B$	—
.36	—	.67	—
.45	.58	.86	—
.50	.73	—	—
.40	.80	.77	1.08
.53	.91	.93	1.19
	.72	.62	—
Mean $0.45B$	$0.71B$*	$0.81B$	$1.14B$

Landscape covered with hazy clouds	$3.5\ B$
Upper sunlit sides of cumulus clouds	5 to 10 B
Under side of massive cumulus clouds	$1.4B$

*Not the same set as in Table II.

10. THE SKY.

Although the most helpful data upon which to base the practical efforts of realizing low visibility for airplanes are those pertaining to the apparent reflection-factors of the various areas in landscapes, data pertaining to the sky is of considerable importance. The former data have been presented also under the designation of " relative brightness." This is a better term but is liable to be confusing. Unless otherwise stated, it always means in this report the brightness of an area relative to the brightness of a perfectly reflecting and diffusing white surface under the same illumination.

Some of the data pertaining to the sky were obtained as indirect checks upon other values but much of the data need not be presented or discussed. It was shown in Fig. 4 that the clear sky varies in brightness throughout a day and usually varies greatly from zenith to horizon. The brightness of the sky in absolute units varies generally between 0.5 and 2.0 lamberts, one lambert being a fair average brightness as measured from the earth's surface.

It is of interest to know the brightnesses of various areas in terms of the sky-brightness B, but these values should not be confused with those values of " relative brightness " which are in reality " apparent reflection-factors." The mean values obtained for various areas are presented in Table III in terms of the zenith sky-brightnesses B.

The values for clouds and for water are discussed in preceding sections (7 and 9) under their respective headings. The upper surfaces of the upper wings of airplanes finished a yellowish-white were several times brighter than the zenith sky. At the critical angles for specular reflection of direct sunlight the values were enormously greater. The brightness of the upper wings as viewed from beneath were about 0.05, the brightness of a perfectly reflecting and diffusing white surface receiving the same illumination that the upper surface of the wings received. As viewed from below these wings in their most translucent portions were only about 0.25 the brightness of the sky on a clear day. On an overcast day they would be only about 0.05 the brightness of the sky. Much of the framework of an airplane is opaque, so it is seen that an airplane as a whole appears very dark when viewed against the sky. These points are discussed further in a later section.

It is interesting to note that the data in Table III were obtained independently from those in Table I, with an instrument of a different type, and on different days. However, when reduced to the same value for water they compare thus:

	Fields.	Barren Land.	Woods.	Water.
Table I	6.8	13.0	4.3	6.8
Table II	7.7	10.9	4.3	6.8

This is an excellent check when all aspects of the problem are considered. Incidentally many checks on the absolute values were made with different instruments.

A number of determinations of the portion of the total light contributed by the sky on clear days were made at the earth's surface. These averaged about 0.16. In other words, the sky contributed about one-sixth and the sun about five-sixths of the total light on the earth's surface during the clear days of this period and in this locality. Let us assume the mean sky brightness equal to B and the brightness of a perfectly reflecting and diffusing horizontal surface due to sunlight equal to $5\ B$. By weighting the values of earth brightness in terms of the mean sky brightness (which is greater than the brightness of the zenith sky) let us assume that the mean brightness of the earth equal to $0.4\ B$. Then

$$RB\ (5+1) = 0.4B$$

$$R = \frac{0.4}{6} = 0.066$$

where R is the mean apparent reflection-factor of the earth. This is approximately the weighted mean arrived at by measurement. Inasmuch as the assumption cannot be far from correct this serves as a check for the data in Table I.

When viewing the earth from high altitudes, the haze which is a luminous veil owing to the light reflected by the suspended particles, may add some brightness to that of the earth. No very accurate measurements of the luminosity of this veil were obtained, but it does not appear to add very much to the mean brightness of the earth when the latter was viewed vertically from a high altitude. As we ascend, the blue sky becomes less bright and more saturated in color. For this reason the brightness of the earth in terms of that of the sky increases with the altitude of observation. Some measurements at altitudes of 10,000 to

20,000 feet on a clear day yielded the following brightnesses in terms of the zenith sky brightness B:

Fields	1.1 B
Water	1.4 B
Landscape covered with thin clouds	3.5 B
Dense sunlit clouds	11.0 B

At very high altitudes the sky was very dark blue and measurements indicated that it was contributing only about 5 per cent. of the total light at midday at an altitude of 18,000 feet. There are reasons for expecting even lower values than 5 per cent. at the highest attainable altitudes. A mean of a number of measurements at 18,000 feet indicated that the lower horizontal surface of a perfectly reflecting and diffusing opaque object (reflection-factor = 1) would be 1.7 times the brightness of that particular zenith sky as observed at that altitude. In accordance with the preceding computation, assuming that the sky was of uniform brightness and contributed 0.05 of the total light,

$$RB\ (19 + 1) = 1.7\ B$$

Therefore R, the mean apparent reflection-factor of the earth would be equal 0.085. Considering that the earth haze may be responsible for some increase in the light which reaches the lower horizontal surface of the theoretical perfectly reflecting and diffusing object the value 0.085 appears to check well with preceding values.

Inasmuch as the brightness of the lower surfaces of airplanes is of interest from the standpoint of visibility as viewed from below against the sky, this aspect will be further considered. The amount of light reflected upward from the earth and the haze was measured on different days. From these observations the brightness of the lower horizontal surface of a perfectly reflecting and diffusing object was determined in terms of the brightness B of the zenith sky.

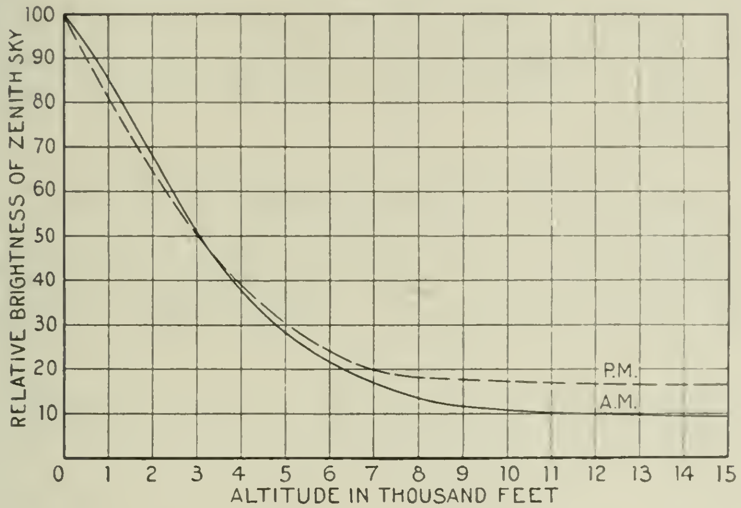
A mean of observations of this value made at altitudes from 7000 to 13,000 feet with a few clouds at 5000 feet was found to be 0.9 B.

A mean of observations of this value made on another day at an altitude of 7000 feet with some clouds at 5000 feet (2000 feet below) was found to be 1.6 B.

A mean of observations of this value at altitudes from 10,000 to 18,000 feet on a fairly clear day was found to be 1.7 B.

In these cases there were no clouds directly below. Unfortunately the number of observations available are insufficient to indicate more than the order of magnitude of this value. The differences in the values presented above are due doubtless to different brightnesses of the sky, to clouds and to various other lighting conditions. From the mean of the three mean values and assuming an average apparent reflection-factor of the earth equal to 0.085 (including the possible contribution of the haze), we compute that the upper horizontal surface of a perfectly white opaque diffusing object would appear about 12 times brighter than the lower surface of such an object above the clouds and haze on a day representing a mean of these three days.

FIG. 12.



Variation of brightness of zenith sky with altitude of measurements, on a very hazy but cloudless day.

From the data in Table I, assuming a mean apparent reflection-factor of the earth equal to 0.07, the upper surface would be about 14 times brighter than the lower surface when the opaque object is a few thousand feet above the earth. Under these conditions, the brightness of the lower side of the opaque object would equal the brightness of the sky (assuming it to be uniformly bright) on a clear day if the sky contributed one-fourteenth of the total light. This latter condition is never obtained at low altitudes.

Certain measurements were made pertaining to the haze. On a perfectly cloudless but hazy day the relative brightnesses of the zenith sky were measured at various altitudes from the earth's surface to 15,000 feet. In Fig. 12 the results are shown for the same.day for morning and afternoon. The point where the curve flattens out indicates the altitudes where the earth haze ends. These points are seen to be at about 10,000 feet and 7000 feet for morning and afternoon respectively on this particular day. These altitudes were roughly checked by others who were asked to estimate the extreme height of the earth haze. It is seen that the brightness of the sky decreases enormously with the altitude. This is of interest in the consideration of the visibility of airplanes as viewed from below.

From the viewpoint of visibility of airplanes as viewed from below, the haze and clouds not only form a veil which tends to obscure the aircraft but also emit light upward, tending to decrease the brightness contrast between the sky and the airplanes. Furthermore, the sky background is of lower brightness at high altitudes. Although it is easy to note the decreasing visibility of airplanes as they ascend to high altitudes, it is necessary to take additional steps to render them of low visibility generally as viewed from below.

II. REFLECTION-FACTORS OF VARIOUS SUBSTANCES.

In developing colors for the camouflage of airplanes it is necessary to reproduce the same reflection-factors or " relative brightnesses " of various earth areas. Besides this, the proper hues

Table IV.

Reflection-Factors of Dry Pigments for Average Daylight.

(See References 2 and 4.)

Pigment.	Reflection-Factor.
American vermilion......	0.13
Venetian red............	.11
Tuscan red.............	.11
Indian red..............	.10
Burnt sienna............	.11
Raw sienna.............	.33
Golden ochre............	.58
Chrome yellow ochre....	.33
Yellow ochre............	.49
Chrome yellow (medium)	.55
Chrome yellow (light)...	.77
Chrome green (light).....	.19
Chrome green (medium).	.14
Cobalt blue.............	.16
Ultramarine blue........	.08
White pigments.........	.70–.90
Black pigments.........	.02–.04

After these pigments have been mixed with vehicles, the resulting paints will possess lower reflection-factors generally than the dry pigments.

must be obtained. These measurements can be made readily with proper apparatus, but it appears desirable to include data on reflection- and transmission-factors of dry pigments and of various other substances. The reflection and transmission characteristics of various types of media will be found in Reference 2.

12. GENERAL OBSERVATIONS.

A general qualitative study of the background and of the size of airplanes at various distances below the observer and above the earth was not only conducted while making photometric measurements but special flights were arranged for obtaining general notes. During this period of the investigation the writer had an opportunity to study a number of experiments on airplane camouflage as viewed from above, which were based merely on the judgment of an artist. Such experimental airplanes served the purpose for general observation which aided in convincing the

TABLE V.

Reflection-Factors of Various Substances.

(See Reference 2.)

	Reflection-Factor.
White blotting paper (dry)	0.70–0.85
White blotting paper (wet)	about 0.55
Tracing cloth	.30– .40
Tracing paper	.20– .30
Newspaper	.50– .70
White writing paper	.70– .75
Yellow copy paper	.65– .70
Parchment	.22
Same (2 thicknesses)	.35
Tissue paper (white)	.40
Same (2 thicknesses)	.55
Black cloth	.02
Black velvet	.004
Sulphur	.80
Cork	.25
Chocolate	.05
Paris green	.40
Manila paper	.50
White plaster	.70– .90
Copper (dull)	.25
Brass (dull)	.25– .35
Gold (dull)	.20
Silver mirror	.70– .90
Polished glass surface	.04
Aluminum (dull)	.60

writer of the necessity for the determination of many factors by extensive scientific measurements. Many of the results have been discussed in preceding sections.

From these and previous observations and considerations it appears that the following are the chief factors to be considered in striving for low visibility of airplanes as viewed from above:

1. Brightness.
2. Hue.
3. Size of pattern.
4 Shape of pattern.

Of these, the first is of greatest importance. From the standpoint of low visibility from below, where the sky is the background, obviously brightness and hue are the two chief factors to be considered.

Camouflage for low visibility as viewed from above will be different in late fall and in winter than in the spring, summer and early fall. As previously stated the important season is that of summer and the portions of the seasons close to it. Although other seasons will be touched upon the following conclusions pertain to the more important season, summer, and its vicinity.

All colors should be very dark shades; that is, mixed with black.

White should never be used.

Any coating which reduces the average reflection-factor below that of the natural yellowish-white of airplanes lowers the visibility generally.

Surfaces should be as dull as possible to avoid glint or highlights.

Apparently on a sunny day more conspicuous patterns and colors may be used owing to the greater contrasts of light and shade and the more generally enlivened landscape than on an overcast day.

All areas including sides and bottom of the fuselage and the surfaces of the wings should have the same general character of camouflage.

The upper side of the lower wing should possess a slightly greater reflection-factor in its central portion than the upper side of the upper wing in order to compensate for the lower illumination on the former area. This should apply somewhat to the lower surfaces of the wings but it must not be carried too far.

Haze is a factor which usually tends to lower the visibility of aircraft. This contributes materially when the observer is at high altitudes or at long distances from the camouflaged craft which is in the haze that is at a low altitude.

Wooded areas are the darkest large areas of the landscape, except, of course, shadows of clouds on a sunny day.

Roads and barren ground are generally the brightest portions of landscapes.

Plain or solid colors for airplanes do not appear as satisfactory as broken or mottled pattern but contrasts in brightness should not be great.

Water when viewed vertically or at angles greater than 45 degrees generally appears of a brightness within the range of brightnesses of various earth areas.

Cultivated fields of growing crops are generally of a brightness closely approximating the mean of the landscape.

13. HUE.

No accurate measurements on the hues of the various earth areas were made, for it did not appear necessary. Nature's colors are generally deep shades, and inasmuch as the mean "relative brightness" (apparent reflection-factors) of the various earth areas were found to be very low, from 4 to 13 per cent., the hues to be used in airplane camouflage as viewed from above must be nearly submerged with black. Besides it is easy to approximate the hues closely by direct comparison of the paints with Nature's colors.

During the summer season, which we are chiefly considering, it is obvious that the yellowish greens of foliage, grass and trees, are overwhelmingly predominant. The dark buffs and other gray yellows and gray browns are seen in barren land and in sunburnt foliage. These two general hues are the most prominent. The shadows are a deep bluish shade on colorless areas and, therefore, are in general a blue-green shade of much lower brightness than the highlights. Inasmuch as the mean apparent reflection-factor of the earth's surface is of such a low value, any colors used for the purpose of lowering the visibility must be mixed with considerable black. This tends to reduce the importance of hue so that it appeared, together with other reasons, unnecessary to measure the hues accurately but to trust to qualitative studies, experience, and direct comparison for reproducing them with sufficient fidelity.

The color of inland water is a muddy greenish tint but partakes slightly of the color of the bottom where shallow.

The approximate mean hue may be arrived at in the following manner for any given landscape: A cardboard disk is laid out in sectors of various angles corresponding to the relative proportions of various types of areas on the earth's surface as estimated from observations and photographs. (These proportions can be accurately determined for any area by time records during flights.) Each sector is painted with the approximate color of the area which it represents, the reflection-factor being such as to closely correspond to that given in Table I. When this disk is rotated rapidly the mean reflection-factor will equal that of a landscape having the same proportions of the different areas. If the mean reflection-factor of a landscape is known, the mean of the disk must be made to equal it without altering the reflection-factors of the individual sectors. Therefore, the angles of the latter must be altered according to requirements.

These expedients do not give the exact hue, necessarily, but the general procedure appears to be satisfactory inasmuch as hue is of secondary importance.

Obviously the mean earth hue in late fall would be a more yellowish or brownish shade than in summer, and in winter it would be a tertiary gray and of a very high relative brightness in snow countries. The reflection-factor of fresh deep snow is about 0.8. The hues of the typical earth areas are not reproduced in color in this paper but the reflection-factors of the various patches as given in Table I and elsewhere, and the descrpition of the hues make it possible to visualize the actual colors. For experimental purposes these colors were mixed fresh from tubes and thinned slightly with turpentine. Inasmuch as the colors of large areas in a summer landscape are unsaturated shades—that is, shades of tints—grays of approximate luminosities or reflection-factors were first made. These were then tinted with color of the dominant hue desired. A given mixture was smoothed with a palette knife and the diffuse reflection-factor was determined photometrically, care being taken to avoid the critical angle of specular reflection. The mixture was altered until the correct reflection-factor and approximately correct hue were obtained in each case. If camouflage were to be adopted on a large scale it will be an easy matter to standardize these samples in proportions by weight of commercial pigments or other coloring media and vehicles. Of course it is difficult to determine the reflection-factors of colored surfaces with high accuracy, but it is easy to attain the accuracy necessary in this work.

The components of the various colors for earth areas are as follows:

Fields.—Black, white, ultramarine blue and chrome yellow. Chrome green could be used instead of ultramarine blue and chrome yellow but the latter combination was used for supplying the green in order to roughly simulate the green of vegetation spectrally. Such a paint was developed shortly after our entrance into the war because it has a decided red component roughly approximating that in the spectrum of chlorophyll. If the airplane were to be viewed through special filters it would be less readily discovered if the spectrum of its coloring more closely approaches that of chlorophyll than would be obtained with chrome green or a combination of Prussian blue and chrome yellow. Owing to the extremely dark shades of green, which the measurements recorded in Table I and elsewhere demand, the foregoing refinement does not appear very essential.

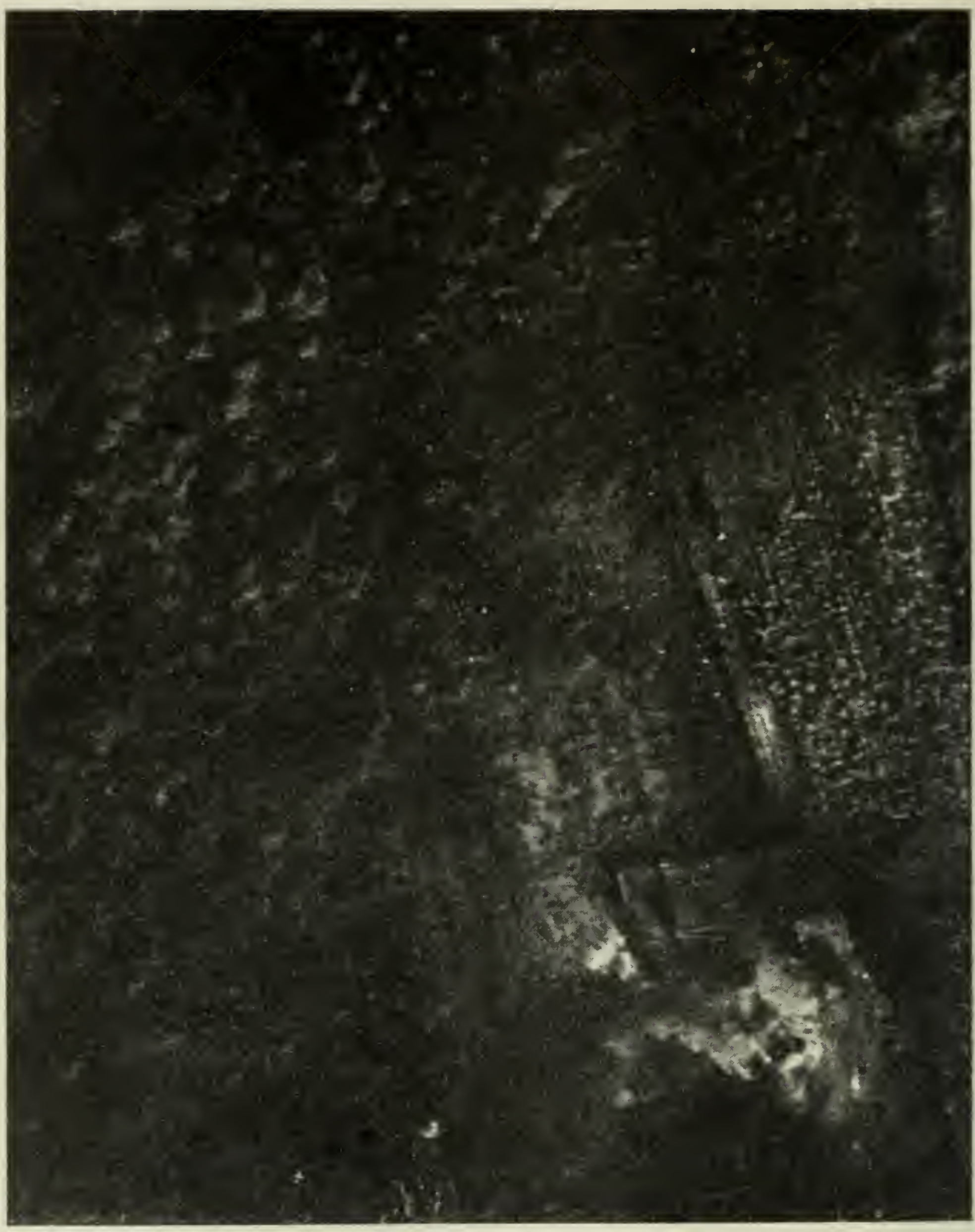
Barren Land.—Obviously the blue will vary considerably with the character of the soil. This color consists of black, white, chrome yellow, and burnt sienna.

Water.—The hue will be somewhat different for shallow and deep water and will vary somewhat for different waters. Usually the variation will be toward green and yellowish green; that is, the bluish tinge will disappear, as the water becomes shallow.

Woods.—The combination is a darker shade of the color for fields of growing crops with a slight addition of blue.

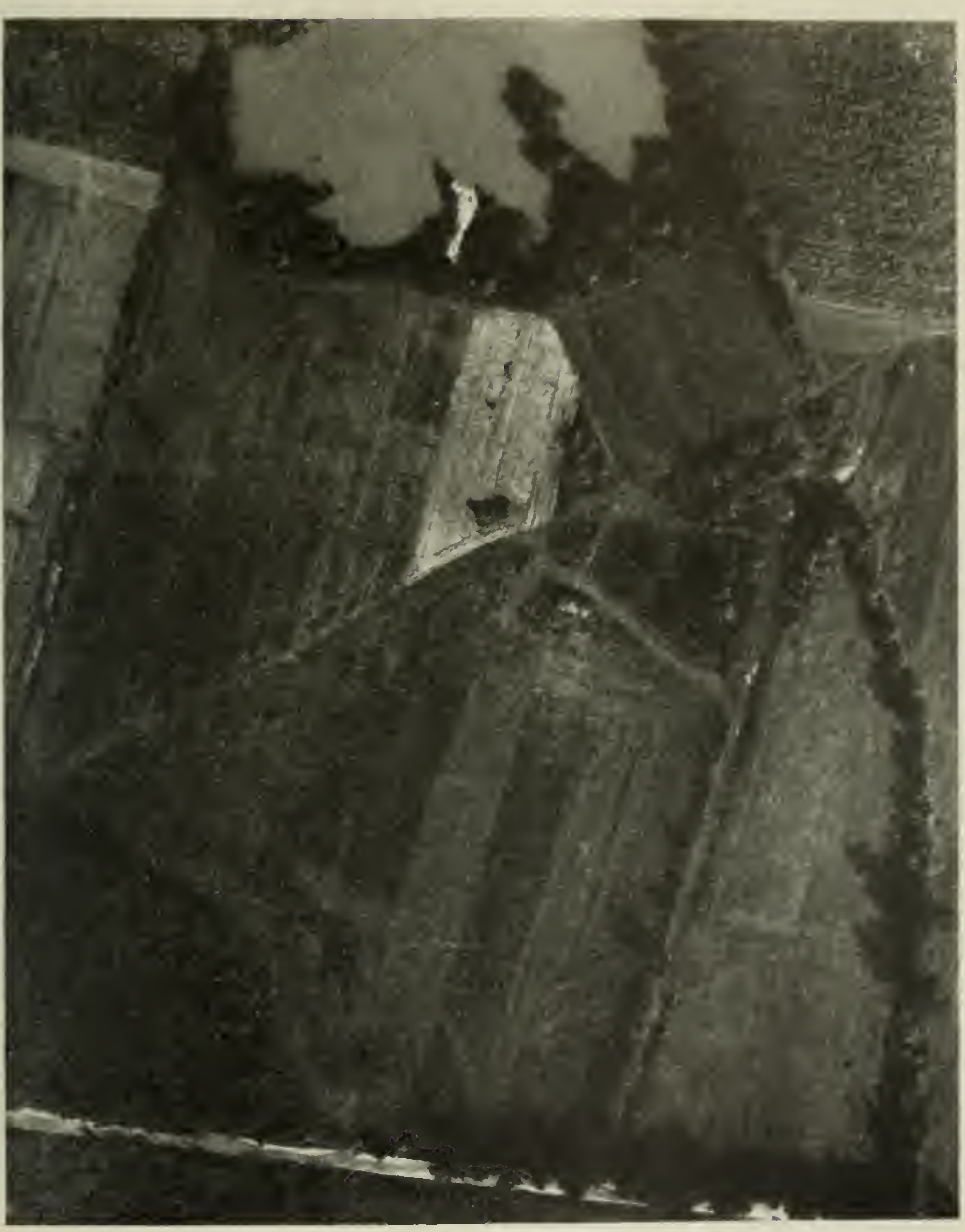
Although the mean colors of various earth areas differ considerably, low visibility for airplanes viewed from above is certainly attainable. Of course, if we could develop a chamelon-like coating which would perform automatically and properly the ideal will have been obtained. Certain iridescent effects might be developed which would be satisfactory if such were necessary. However, it appears that the recommendations in this paper, if applied in practice, will render airplanes of exceedingly low visibility generally.

FIG. 13.



Landscape from 1000 feet.

FIG. 14.



Landscape from 2000 feet.

14. PATTERN.

The size of the pattern (if any) to be used in camouflage aimed to render airplanes of low visability as viewed from above, is of more importance than the actual shape. An airplane of 50-foot spread is a very small object when viewed at a few thousand feet; however, some slight pattern or mottling appears to be desirable. This feature was studied first by viewing various airplanes in flight, with different patterns and colors upon them, from positions varying from a few hundred feet to ten thousand feet above them. At the latter distance the airplanes were such tiny objects that pattern was of little importance. In fact, the importance of pattern decreased rapidly as the distance of observation increased beyond 5000 feet.

In order to study pattern carefully a series of photographs (4 in. × 5 in.) was taken of the same general landscape at altitudes of 1000, 2000, 3000, 5000, and 10,000 feet. These are shown respectively in Figs. 13, 14, 15, 16 and 17, and it will be noted that the characteristic areas of landscapes are present in most of them. In Fig. 18 the curve indicates the size of the image of a 50-foot object at various distances for the same photographic reduction as exists in the preceding series of photographs (Figs. 13 to 17). The focal length of the lens of the camera was 8.5 inches, therefore, if

h = altitude in feet, and
x = length in inches, of a 50-foot object

$$\frac{x}{8.5} = \frac{50}{h}$$

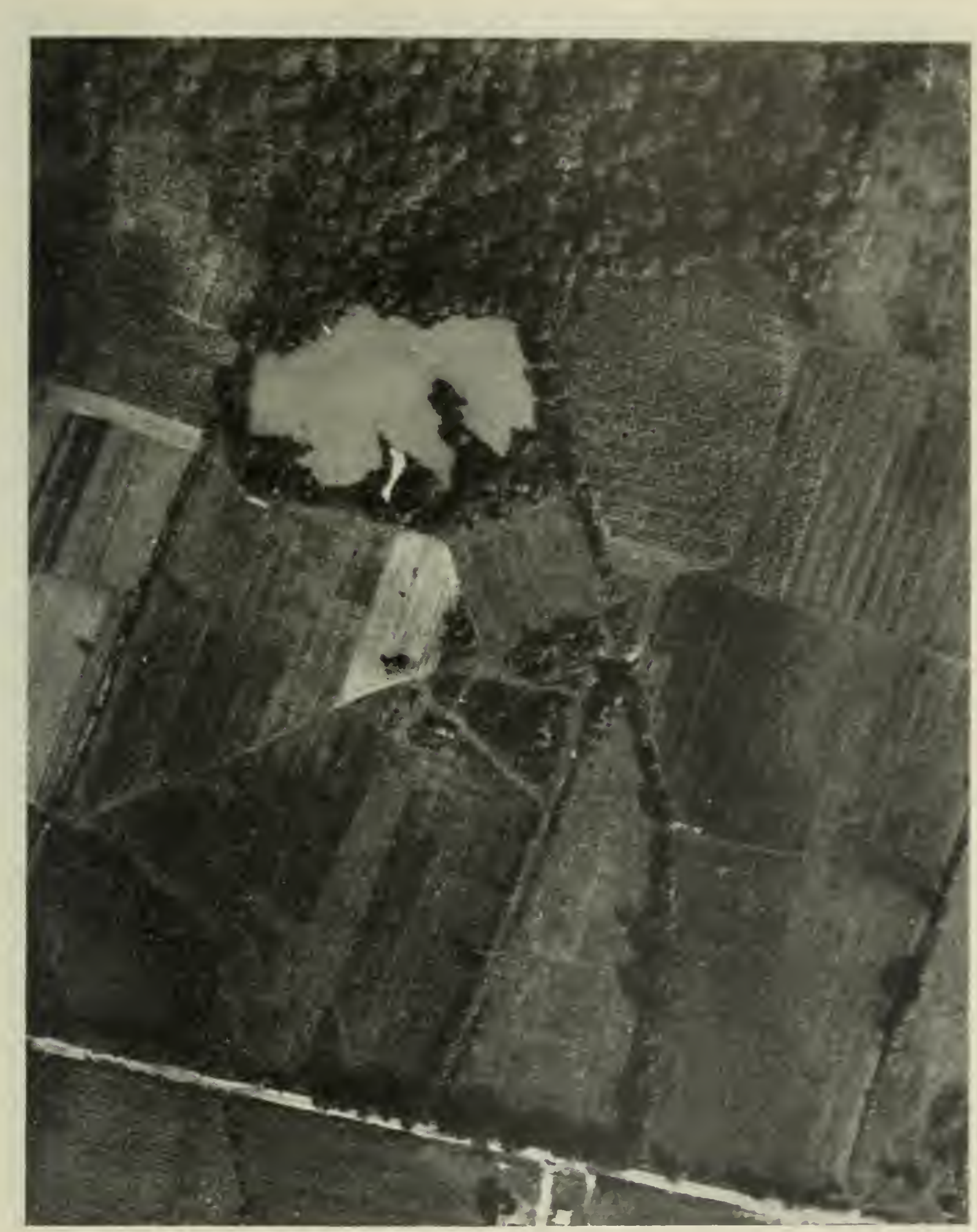
$$xh = 425$$

From this formula the sizes of images of a 50-foot object on the 4 in. × 5 in. photographs for different distances are as follows:

Distance.	Size of image.
1000 feet	0.425 inch.
2000 feet	.213 inch.
3000 feet	.142 inch.
5000 feet	.085 inch.
10000 feet	.043 inch.

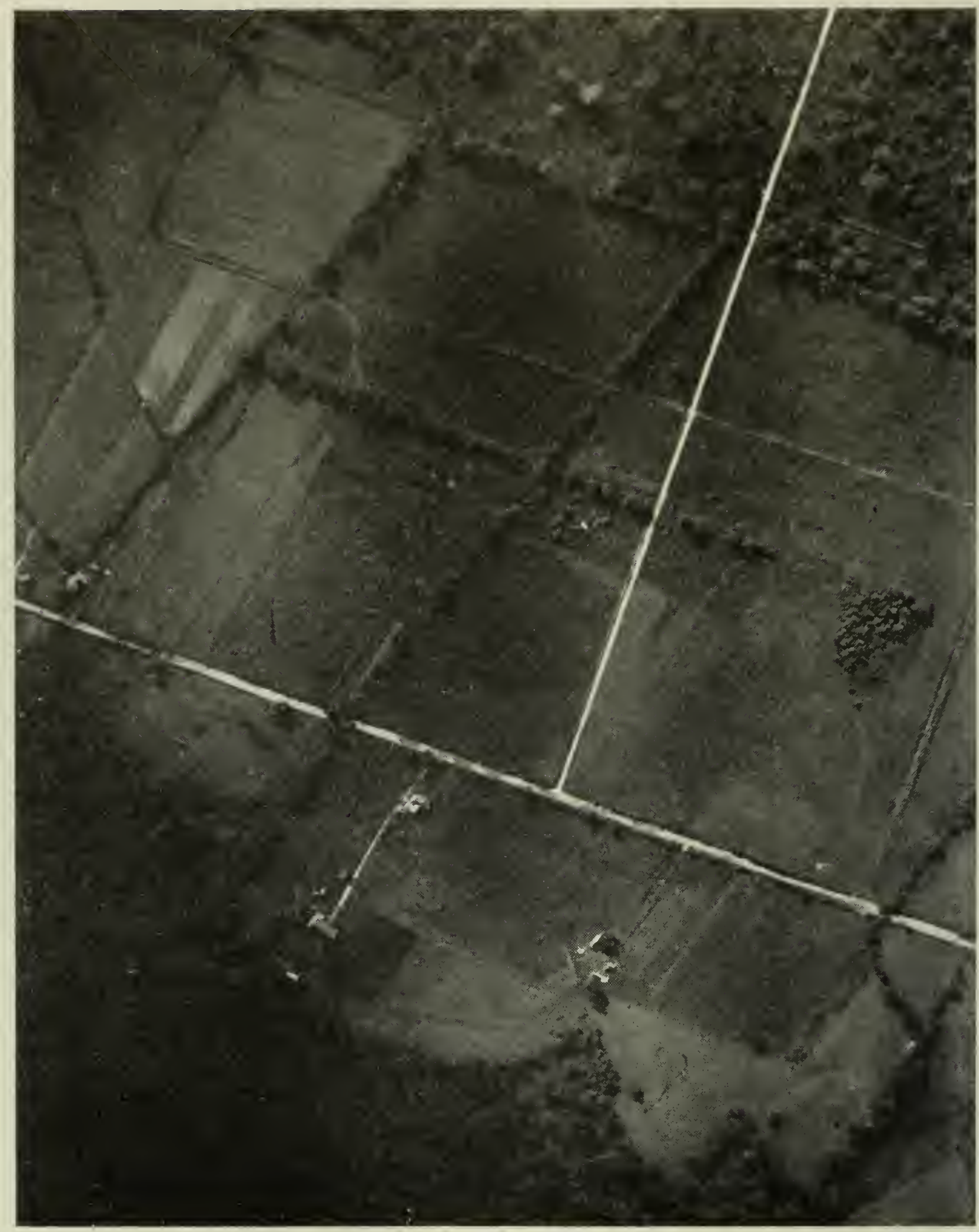
For simplicity assume the spread of an airplane wing to be 50 feet and its width to be 5 feet. Then small rectangles, with lengths in inches given above and with corresponding widths one-tenth the length, can be superposed upon the photographs. Thus the size

FIG. 15.



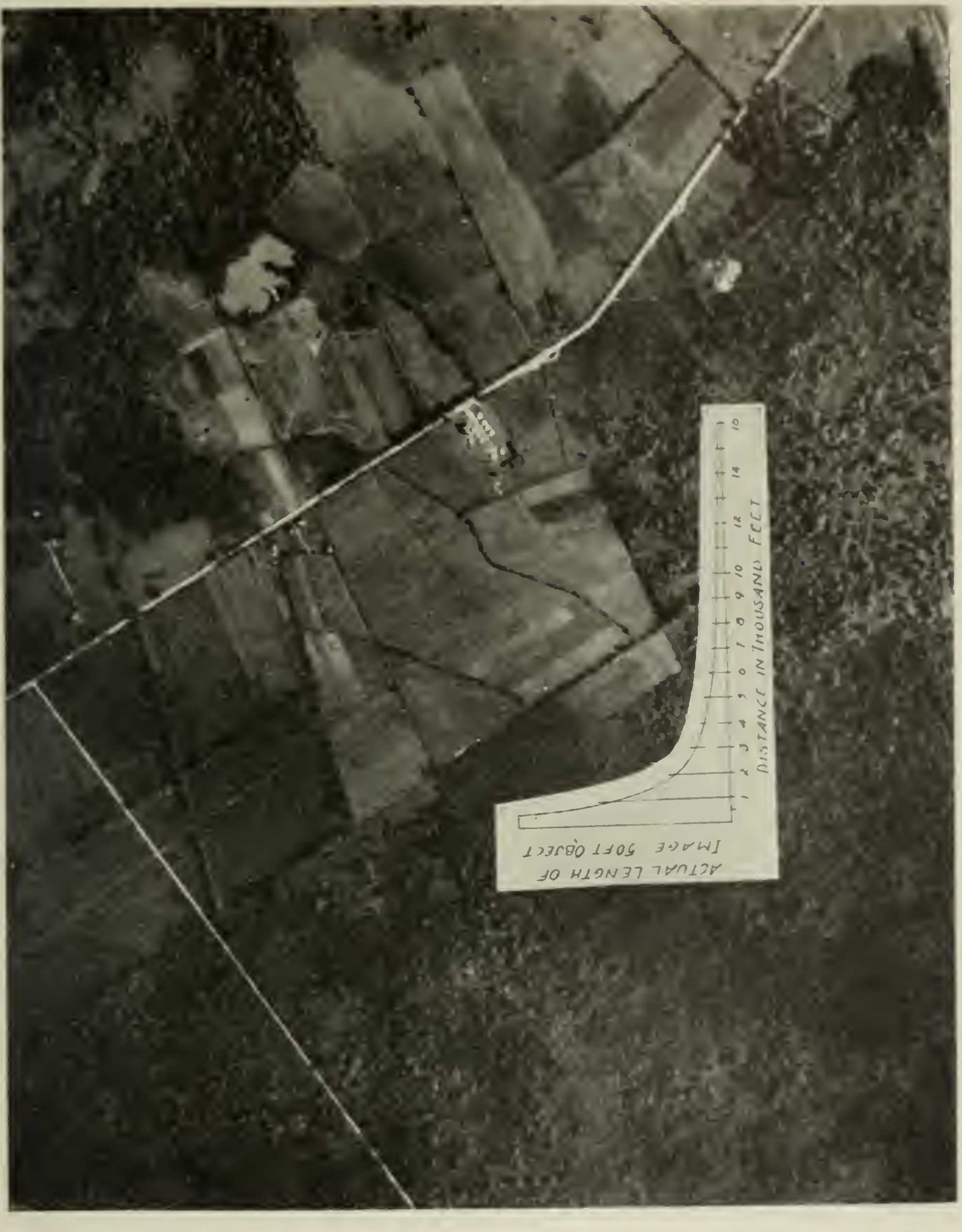
Landscape from 3000 feet.

FIG. 16.



Landscape from 5000 feet.

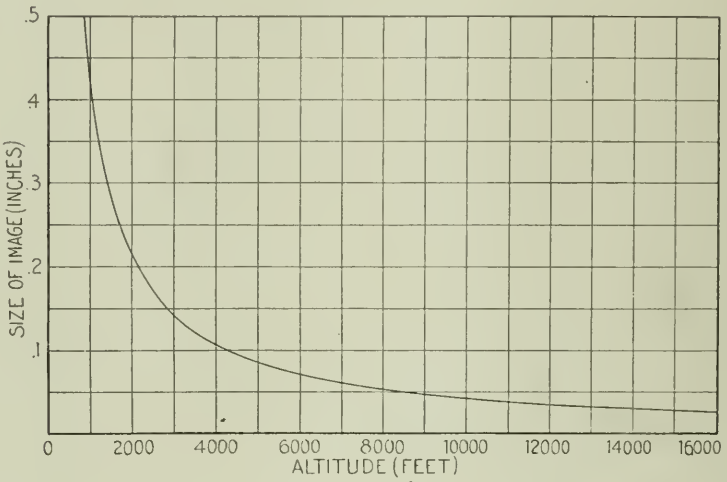
FIG. 17.



Landscape from 10,000 feet. The superposed curve shows the size of the image of a 50-foot object at various altitudes relative to the size of background patterns.

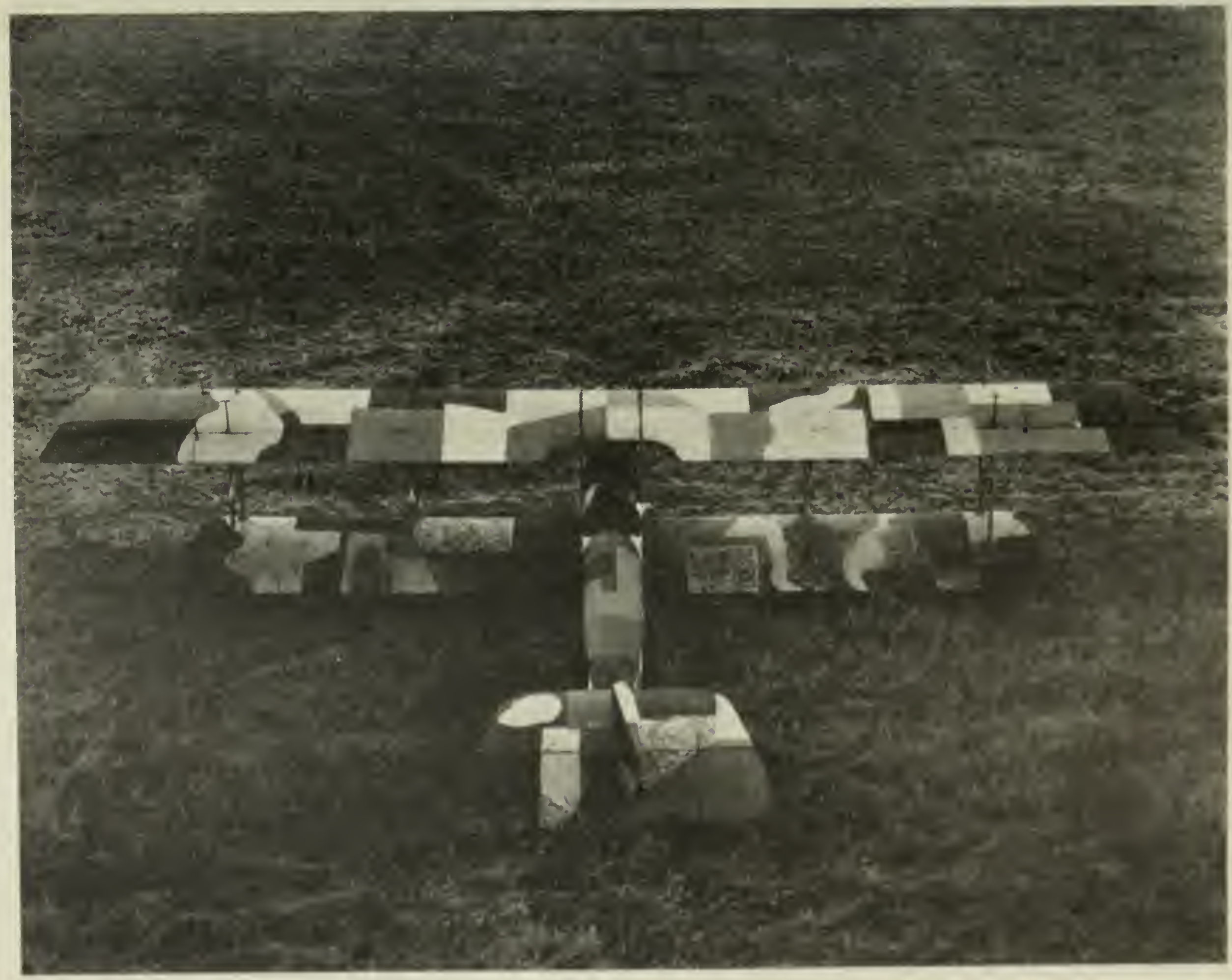
of an airplane at any altitude can be superposed upon this series of pictures in its truly relative dimensions. A curve showing the actual length of the image of a 50-foot airplane at different distances is superposed on Fig. 17. That is by this means an image of an airplane can be placed at any altitude between the earth and the observer and pattern can be studied in a positive manner. Unfortunately in this paper the illustrations are quite small for superposing these various rectangles for the purpose of studying size and shape of pattern for airplane camouflage, although much information can be gained from them. In the original work the photographs were sufficiently enlarged so that this method was satisfactory for studying pattern. However, combining such experiments with experience at various altitudes in studying airplanes below, it is perhaps safe to confine the attention entirely to pattern requirements for airplanes within the range of 1000 to 5000 feet below the observer. From these photographs it is seen that it is futile to adopt a pattern (with many individual areas) which aims to simulate the irregular checkerboard appearance of cultivated fields. At any appreciable distance from the observer an airplane, regardless of its height, would generally be seen against a background consisting of a single field or at most two or three fields. This, if done accurately would be equivalent to painting the airplane almost a solid color or at most with only two or three areas of different contours and very slight contrast.

FIG. 18.



Showing relation between size of image of 50-foot object and altitude or distance. These values are correct for 4 inch by 5 inch reproductions of Figs. 13–17.

FIG. 19.



Illustrating some of the things which should not be done. Patterns very much too small; contrasts very great, colors not dark enough; light colors and white should never be used for camouflage to be viewed from above.

Although pattern is not of chief importance, it appears essential to use it to some degree in this type of camouflage. After studies of these photographs and many visual observations from various altitudes it appears that one of the best patterns which could be adopted would be a simulation of woods. This would provide pattern of a mottled sort (a very dark green with nearly black shadows), and inasmuch as clumps of trees are commonly found isolated in a landscape such a pattern would be appropriate over any area. The mean reflection-factor of this pattern might be a compromise of the apparent reflection-factor of various typical areas, but if such a pattern is adopted it appears best to have it appear not more than slightly brighter than dense woods so that it would be of low visibility over wooded areas. In fact, if it were of the same brightness and pattern as woods, the airplane would be practically invisible over wooded areas and apparently no more conspicuous over other areas than it would be if its brightness were a mean of the landscape brightnesses.

On the basis of the preceding photographs and of the information yielded by a study of Figs. 13 to 17, with the sizes of the images of the 50-foot airplane properly superposed, it is evident that the pattern of Fig. 19 consists of areas entirely too small. Furthermore, the areas of high brightness approaching white cause the airplane to be distinguished readily as it is moving over the more uniform areas such as fields and woods. Many other patterns were shown to be futile attempts at attaining low visibility of airplanes as viewed from above. Invariably attempts at camouflage for airplanes viewed from above were faulty in pattern and the colors used were not dark enough.

15. VISIBILITY OF AIRPLANES AS VIEWED FROM ABOVE.

Much of the material in previous sections may be considered prefatory to the following discussion. Many of the photometric data were obtained for the purpose of placing this type of airplane camouflage on a scientific basis. Such work should not be left to judgment based upon limited qualitative visual observations because the final efforts must necessarily be compromises aimed to strike the mean. Only definite measurements can establish such mean values.

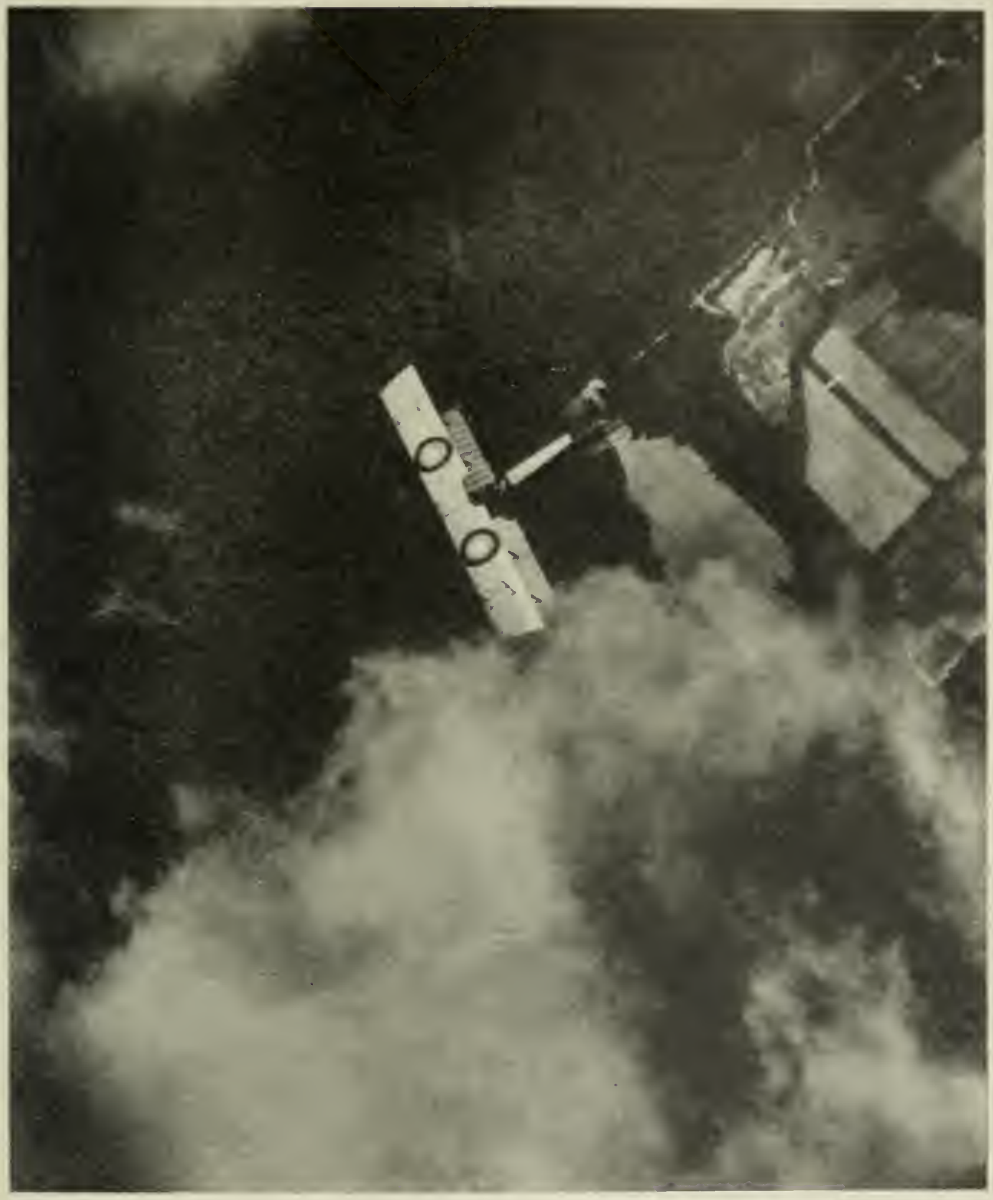
Airplanes whose chief activities are carried on at low altitudes predominantly over friendly territory, such as may be the case in certain patrol operations, would ordinarily be in danger chiefly from enemies overhead. Such aircraft can be camouflaged successfully for low visibility as viewed from above. The earth is the usual background, although in the case of low clouds these would sometimes be below such airplanes; however, clouds would often serve as a screen. Sunlit clouds are many times brighter than the earth as shown in Section 7. Although they vary in brightness, their sunlit sides are of the order of magnitude of ten times the mean earth brightness. Owing to this fact camouflage cannot be successfully worked out on the same airplane for both earth and cloud backgrounds. Furthermore, the earth is the background that is overwhelmingly present and, therefore, it is the one which will be considered in the present discussion.

The various types of areas of the earth's surface, such as woods, fields, water, and barren land, differ somewhat in relative brightness or in apparent reflection-factors, although their mean values were found to be quite constant and not very different on various days as seen in Table I and other tables. They also differ in pattern and hue; however, brightness is the most important factor. When the observer is at great heights or distances, pattern becomes of relatively little importance owing to the fact that the airplane appears scarcely larger than a speck. When he is at high altitudes or great distances the importance of color also diminishes to a small degree. However, the importance of brightness persists until the camouflaged airplane dwindles beyond a minute speck or until it is otherwise invisible.

It is quite obvious if the investigation of camouflage of the type under consideration at present is left to judgment by experimenting with various colors on airplanes, the best practice could not be determined with certainty. For example, an airplane provided with a pattern of certain hues and reflection-factors, might be fairly inconspicuous over a wooded area and be quite conspicuous over ploughed or barren land. Furthermore, if no measurements were applied, our experimentally camouflaged craft would be either visible or invisible in the absence of a scale of visibility. As a matter of fact, all experimental craft would doubtless fall in the "visible" class. Visibility scales could be established by using a neutral absorbing wedge or a series of absorbing screens arranged in steps according to their transparencies. An instrument might be utilized which would introduce a luminous haze or veil and the intensity of the luminous veil required to render the craft invisible might be taken as a measure of its visibility. These methods were tried more or less incidentally to illustrate the difference in the visibilities of aircraft painted differently, but inasmuch as such experiments involve the disadvantage of requiring extended aerial sojourns above the camouflaged craft by a number of observers, they were not considered practical. This decision was also hastened when it became evident that the mean relative brightness or reflection-factor of the earth and its typical areas could be determined by means of photometric apparatus. After such values were obtained it would be an easy matter to provide an airplane with a coating of proper reflection-factor. The mean hue could also be obtained but it early appeared evident that this could be satisfactorily approximated by certain methods based primarily upon a fair knowledge of the earth's coloring. The pattern could also be determined fairly satisfactorily as is illustrated in Section 14.

The high visibility of airplanes of yellowish-white finish viewed against the earth as a background is very evident even to a casual observer. This is well illustrated in Figs. 8 and 20. The earth background, including the barren and ploughed areas, are much darker than the uncamouflaged craft. This is quite evident in Figs. 8 and 20 for the wooded area, but the limitations of photography are somewhat misleading for the brighter areas. Of course, in the rare case of viewing an airplane against a cloud background, the visibility of the airplane with light finish is lower than a craft with a very dark finish. However, the clouds would more often form a screen from the enemy for low-flying craft whose operations would ordinarily be confined below the ordinary altitude of cumulus clouds. The airplane shown in Fig. 8 was about 200 feet below the photographer. As the distance of the craft increases, its size very rapidly diminishes. The earth shown in this illustration was about 6000 feet below the camera. It is seen in this illustration that a pattern, which aimed to simulate the irregular checkerboard pattern of cultivated fields, if applied to an airplane, would consist of only one or at most two or three areas on the entire airplane. In order not to be confused at this point, the reader should refer to Section 14 in which pattern is discussed at length. For reasons discussed in that section it

FIG. 20.



Showing approximate brightness relations of uncamouflaged airplane, clouds and landscape.

appears that one of the most desirable patterns which could be used would be that which simulates woods. Notwithstanding the values of apparent reflection-factor which are available in Table I, the best value of the mean reflection-factor for a camouflaged airplane depends somewhat upon the basis for adopting the particular pattern. For example, if the simulation of woods were chosen, the mean reflection-factor would perhaps be best if it were close to that of wooded areas in summer, namely, about 4 or 5 per cent. The size of the pattern might best be adjusted for an airplane 5000 feet above the earth and 5000 feet below the observer. Clumps of trees are common in most landscapes so this pattern appears feasible although, of course, the shape of the craft would contribute somewhat toward its detection. Inasmuch as the airplane is likely to be viewed at distances of several thousand feet predominantly, the pattern would approach full size; that is, it would be rather large. It would be made by using a very dark shade of green for the highlights and a bluish black for the shadows. No artistic painting would be necessary.

Referring to the mean values in Table I we have the apparent reflection-factors for various types of areas, namely,

Woods	0.043
Fields	0.068
Barren land	0.13
Inland water	0.068

In the original report the colors of these respective brightnesses and aproximately correct hues were shown, but it is impracticable to do so here. If a pattern were to be adopted which contained areas simulating the hues and brightnesses which were determined, the desired proportions of this could be used. I do not favor such a pattern (represented in Fig. 19) because, the airplane being a moving object, is readily distinguished by the moving brighter areas as the craft sails over the darker areas of landscape. The movement of darker objects over the brighter areas is not generally as noticeable; at least this appears to be true for the range of brightnesses with which we are concerned. One of the chief obstacles in the use of such definite and contrasty patterns is the fact that the camouflaged craft is moving.

Solid or uniform color over the entire plane is not fully satisfactory because the background is never perfectly uniform except over water. Therefore, there is some compromise which is the best pattern. As seen in Section 14, with the exception of woods, crops, etc., the earth's pattern is entirely too large to be simulated on an airplane. This leaves us scarcely any other pattern except a mottled one of large indefinite figures. A very subdued pattern is more promising than such a one as Fig. 19. In fact, according to the values in Table I, the mean reflection-factor of any successful pattern must be very low. Ordinary commercial "black" paints often reflect as much as 0.03 of the incident light, so it is seen that the mean brightness of the earth approaches that of "black" paint under the same illumination.

If the mean apparent reflection-factor and mean hue of a certain landscape are desired, these can be obtained approximately by estimating or determining the proportions occupied by the various areas and using the mean values in Table I. For example, the following would be the procedure for one region among those studied at the particular period of the year:

Area.	Apparent reflection-factor.	Portion occupied.	Total contribution.
Woods	0.043	0.40	.043 × .4 = .0172
Fields	0.068	.30	.068 × .3 = .0204
Water	0.068	.10	.068 × .1 = .0068
Barren	0.13	.20	.13 × .2 = .026
Mean			.07

The mean apparent reflection-factor of this landscape is therefore approximately 0.07. This is shown in color in the original report. A circle is divided into sectors corresponding to the proportions of the total area occupied by the different types of area respectively. These sectors are painted with paints of corresponding reflection-factors and approximate hues. When this color-wheel is rapidly rotated the mean color and reflection-factor is obtained. The mean color in this case is a very dark greenish gray.

It is impracticable to carry this work further in this paper. The essential details, measurements and limits have been established and they may be readily combined to meet the conditions of the landscape which will actually form the background for airplanes viewed from above. With the data in this paper it is possible to develop camouflage for other seasons of the year which should be satisfactory in practice. In winter it should be easy to copy the landscape in a country where snow lies on the ground. Barren spots can be directly copied with the aid of the measurements herein recorded and the snow can be simulated by white paint. Where snow predominates it would appear best to paint the airplane a dead white on the upper surfaces. It would thus be of extremely low visibility over snow-covered areas, and even though visible over barren areas it would become of low visibility to the enemy again as it passed between a snow area and the enemy. It is surprising how difficult it is to keep an airplane under observation if it is colored to simulate even a portion of the landscape. The angular extent of the visual field is so limited that despite the efforts of the pilot, his view or that of the observer, is often interrupted by the wings and body of the craft. These are practical conditions which help to make camouflage feasible for airplanes.

In this type of camouflage it is advisable to use a matte or flat paint. It would also be feasible to incorporate the coloring media in the approved varnishes, but unfortunately these are glossy. Obviously it is essential to use vehicles which do not attack the dopes and varnishes already approved for airplane fabric. These are problems concerning which information is available and they can be readily met.

Of course, some consideration must be given to insignia. Instead of two, one on each wing, these might be reduced to one; in fact, they might be confined to the sides of the fuselage and lower sides of the lower wings. I have been told that ships are recognized as to nationality by other distinguishing features. Surely insignia are practically useless at a distance of a few thousand feet. At any rate, the white area could be reduce to a gray. Considerable attention was given to this problem and it offers no discouragement.

16. VISIBILITY OF AIRPLANES AS VIEWED FROM BELOW.

In this case the sky and clouds form the background, and in order to achieve complete invisibility the lower surfaces of the airplane must be rendered equal in color and brightness to the background. An obvious ideal would be an airplane of complete transparency so that the background could be viewed through the transparent media, unaltered in color and brightness. This consideration led to experiments on transparent or partially transparent media. After some experiments it appeared that a partially transparent fabric could be obtained by incorporating a fabric or coarse mesh in a transparent medium such as "celluloid" or gelatine. However, perfect transparency cannot be realized and various practical considerations led to a less sanguine view of such an application. For example, there is much opaque material in an airplane and the projected area of this opaque material rapidly increases in percentage of the total projected area of the airplane as the angle of view becomes more and more oblique to the craft. Another point worthy of consideration is that even a sheet of clear glass has a transmission-factor of not more than 0.92 and it is not expected that a practicable fabric could be devised which would have a transmission-factor exceeding 0.5. From the standpoint of invisibility, as viewed from below, it is desirable to use as transparent or translucent material as possible and to employ colorless dope and varnishes. Bleached linen, white silk, and cotton would be better than the yellowish unbleached linen from the present point of view. Ordinary airplanes with yellowish finish are at present conspicuous against a blue sky on a sunny day not only on account of their much lower brightness but also owing to their distinctly yellowish color. This must be corrected to the unsaturated blue of the sky.

Of course some of the brightness of the lower surface of an object in the air is due to the light reflected by the earth to it, but this is a small part of its total brightness if the object is fairly diffusely transmitting. The limits of this additional brightness contributed by the reflection of the earth's surface can be computed by assuming the conditions of an overcast day and a clear day respectively. For the sake of clearness let us assume first a horizontal diffusely reflecting opaque object in the air on an uniformly overcast day. If the average reflection-factor of the earth is 0.1, the lower surface of the diffusely reflecting surface will have a brightness of 0.1 RB, where R is the reflection-factor of the object and B is the brightness of a uniform sky. In other words, a perfectly white diffusely reflecting opaque object under these conditions could not be more than one-tenth the brightness of the sky; that is, the limiting brightness is dependent upon the average reflection-factor of the earth. It will be seen that an airplane or any opaque or translucent object is more generally conspicuous when viewed against the sky on an overcast day than on a clear day.

Assuming on a clear day that the sun contributed 0.8 of the total light which reaches the earth, then the earth's average brightness will be 0.5 B if its mean reflection-factor is 0.1 and B is the brightness of the sky. The brightness of the lower surface of a perfectly white diffusely reflecting opaque object will now be 0.5 RB where R, as before, is the reflection-factor of the lower surface. In other words, the object under these conditions will be less conspicuous when viewed against the sky on a clear day than on an overcast day. Assuming $R = 0.8$, which is a value obtainable with so-called white pigments, then the ratios of the brightness of the lower surface of the horizontal opaque object to that of the sky will be

$$\frac{0.1 \times .8 \times B}{B} = 0.08 \text{ on an overcast day, and}$$

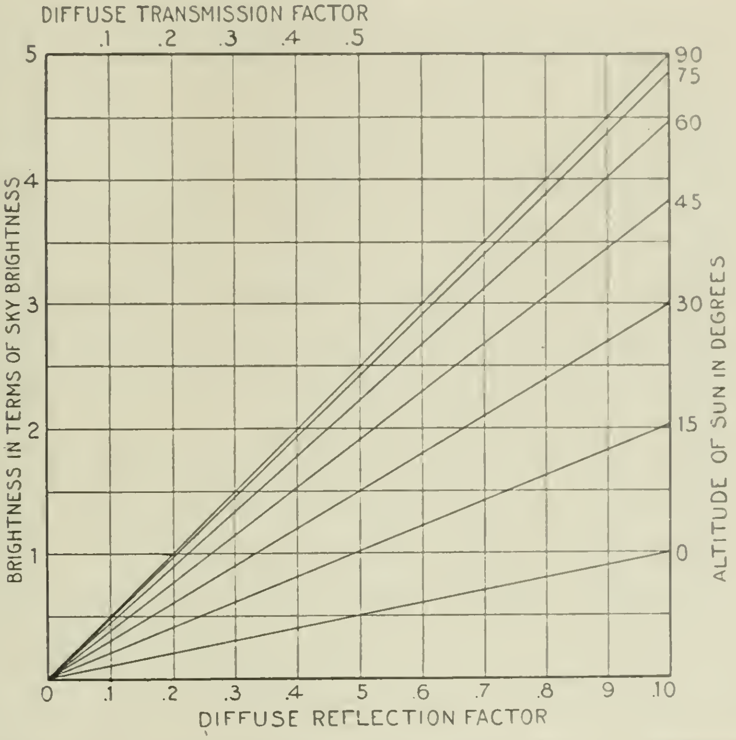
$$\frac{0.5 \times .8 \times B}{B} = 0.4 \text{ on a clear day,}$$

with the conditions as assumed. In the two cases B might not be the same but its absolute value is of little consequence. Contrasts are the important factors in visibility. Obviously, if the reflection-factor of the earth were unity (a perfect white) the brightness of the lower surface of the diffusely reflecting object would be much greater. Under these conditions, if $R = 1$, the object would be as bright as the sky on an overcast day and 5 times the brightness of the sky on the clear day under the conditions assumed.

The foregoing analysis touches merely a few salient points for the purpose of indicating the phases to be considered. It is seen that, on the sunny day assumed, a diffusely transmitting medium would be of about the same brightness as the uniform clear sky at noon if its transmission-factor were 0.4, without taking into account the effect of light reflected upward from the earth. On sunny days translucent media of proper tint generally would be more satisfactory than transparent media for airplanes because of the direct contribution of light by the sun. On overcast days the advantage would be with the transparent medium; however, it appears quite possible that in consideration of all practical aspects a diffusing medium of fairly high transmission-factor and bluish tint would be more generally satisfactory than the partially transparent medium. Furthermore, on overcast days the clouds are usually so low that high-flying airplanes would be far above them.

Let us consider the possibilities obtainable with opaque material for the wings but painted with diffusely reflecting coatings and also those obtainable with translucent fabrics which are diffusely transmitting. A few diagrams will illustrate the range of practical possibilities. Some of the discussion pertaining to Figs. 1 to 7 will serve as an introduction to the discussion which follows. Obviously it would be futile to attempt to analyze the conditions for an average sunny day when there are numerous clouds in the sky, so that only skies of uniform brightness will be discussed for a complete range from an overcast day to a very clear day. On this basis any object is illuminated by light from the uniformly bright sky and by direct light from the sun which varies with the altitude and with the clearness of the atmosphere. Direct sunlight scattered by the atmosphere makes its contribution toward the illumination of an object as light from the sky.

FIG. 21.



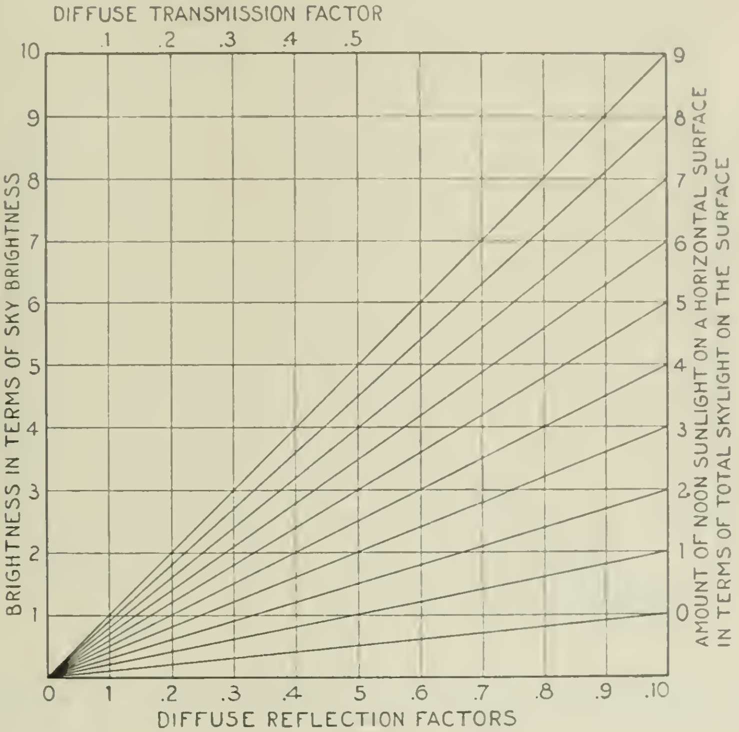
Brightness (in terms of sky-brightness) of upper horizontal surface of a diffusely reflecting object and of lower horizontal surface of diffusely transmitting object under various conditions. Sun contributes 0.8 total light at midday; sky of uniform and constant brightness.

In Fig. 21 the sky is assumed to be of uniform and constant brightness throughout the day and 0.8 of the total light which reaches the earth at midday is assumed to come directly from the sun. The latter assumption is a fair average for clear days although the value is greater on days when the sky is deep blue in color (very little haze) and is lower on very hazy days. The sky-brightness equals B and the relative brightnesses of the upper surface of diffusely reflecting opaque objects (of various reflection-factors) are determined in terms of B for various altitudes of the sun. The relative brightnesses of the lower surface of diffusely transmitting objects are considered simultaneously. For simplicity the total absorption of the earth haze is assumed to be constant regardless of the altitude of the sun. This obviously is not the case, but inasmuch as these diagrams aim to show merely the range of possibilities these assumptions are considered to be satisfactory. The scales for the diffuse reflection- and transmission-factors are respectively at the bottom and at the top of the diagram. Inasmuch as a perfectly diffusely transmitting and non-absorbing flat object will diffuse as much light backward as forward (see Fig. 6) the maximum diffuse transmission-factor is 0.5. Therefore the upper scale ends at 0.5.

When the sun's altitude is zero the condition is that of an overcast day or before sunrise and after sunset on a clear day (assuming the brightness of the sky to be uniform). A perfectly diffusely reflecting opaque object under this condition will be equal to the brightness B of the sky or, in general, the brightness of a diffusely reflecting object will be equal to RB (see Fig. 6) where R is the diffuse reflection-factor. Under similar conditions, the transmission-factor being equal to T, the brightness of the lower side of a diffusely transmitting object will be equal to TB. The brightness of a perfectly diffusely transmitting object ($T=0.5$) under a sky of uniform brightness B will equal 0.5 B whether viewed from above or below, whereas the brightness of the upper surface of a perfectly diffusely reflecting object ($R=1$) will equal B. These facts are indicated in Fig. 21. Inasmuch as we are primarily concerned with diffusely transmitting media in the present discussion, the upper scale is of chief importance. The area representing the conditions under which a diffusely transmitting object may be brighter than the sky background can be readily isolated on the diagram. At midday it is seen that a horizontal diffusely transmitting medium, with $T = 0.2$, will appear of the same brightness as the sky when viewed from underneath. No contribution of light reflected upward from the earth is considered in this diagram.

A somewhat similar diagram is shown in Fig. 22, except that the condition is assumed to be midday (sun's altitude 90 degrees) and the sun is assumed to contribute various proportions of the total light which reaches a horizontal surface. The scale for the latter is on the right of the diagram where it is seen that the diagram covers the conditions when the sun contributes from zero to 9 times the amount of light contributed by the uniform sky upon a horizontal surface. This range represents practically the entire range of proportions measured at the earth's surface. As indicated in a previous section, this proportion greatly increases at high altitudes. On the diagram the area representing the range in which the under side of diffusely transmitting objects may be brighter than the sky background is readily distinguished. How-

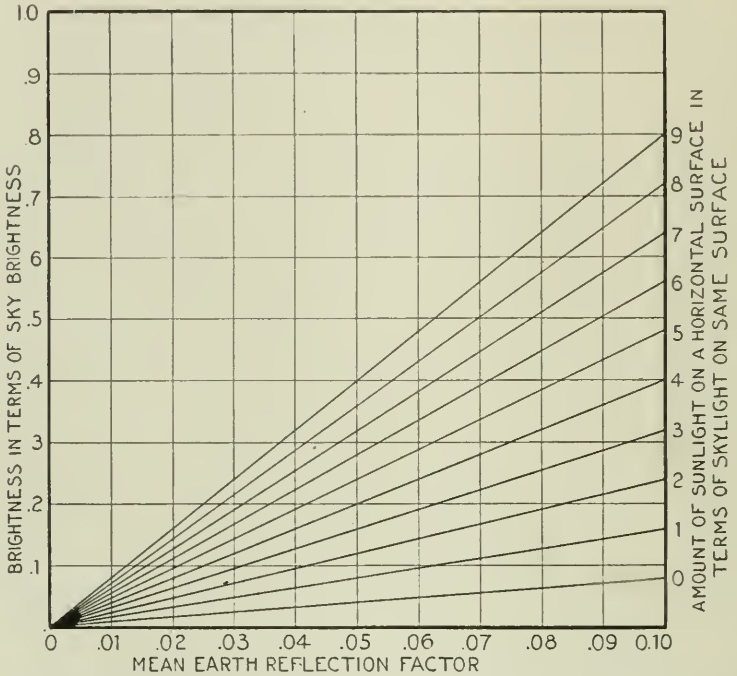
FIG. 22.



Brightness (in terms of sky-brightness) of upper horizontal surface of diffusely reflecting object and of lower surface of a diffusely transmitting object under various conditions. Sun at zenith and contributing various times as much as sky which is of uniform brightness.

ever, there is some light contributed to this under side by reflection from the earth. For simplicity the mean reflection-factor of the earth may be assumed to be 0.1 and ½ of the light which it reflects upward to the diffusely transmitting object may be assumed to be diffused downward from the diffusely transmitting medium. This contribution due to reflected light from the earth would slightly extend the region on the diagram in which the brightness of the under side of the diffusely transmitting object

FIG. 23.

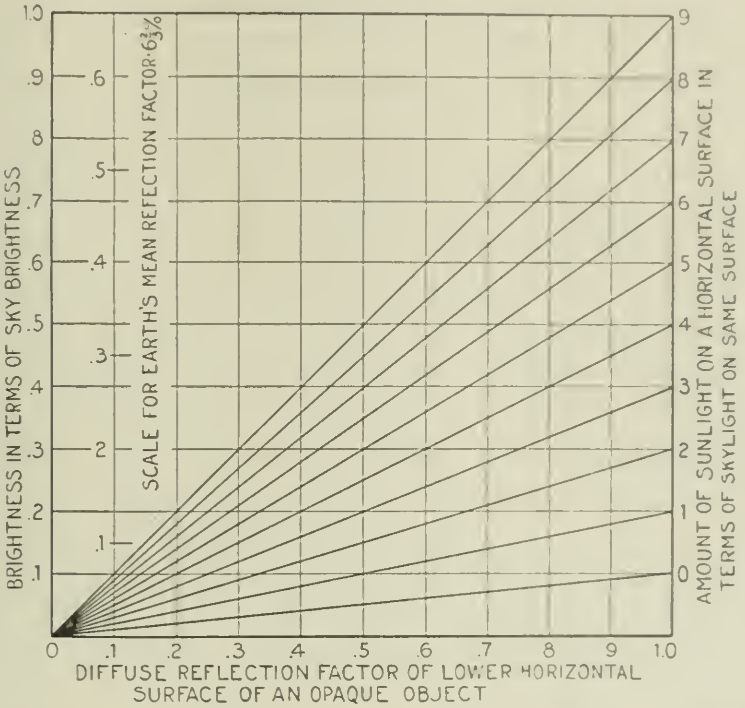


Brightness (in terms of sky-brightness) of lower horizontal surface of a diffusely reflecting opaque object whose reflection factor is 0.8. Time is midday, sky is uniform in brightness, and sun is assumed to contribute various proportions of the total light.

is brighter than the sky background, but it is not shown in the diagram.

In Fig. 23 another aspect is analyzed, namely, the brightness of the lower horizontal surface of an opaque object painted with a commercial flat white pigment possessing a diffuse reflection-factor of 0.8. The natural lighting conditions are assumed to be a sky of uniform brightness with the sun contributing from zero to 9 times the amount of light that reaches the earth from the sky. The light which reaches the earth is partially reflected upward depending upon the mean apparent reflection-factor of the earth. According to photometric measurements the portion of the total reaching the earth which is reflected upward lies between 0.05 and 0.1 for summer landscape in fertile countries. It is seen that under the range of conditions assumed, the lower surface of the horizontal object which is painted with the commercial flat white cannot be as bright as the sky. Inasmuch as this range includes the best conditions that could be expected, low visibility as viewed from below, cannot be realized for low altitudes by painting the under sides of an airplane an opaque white. The reflection-factor of aluminum paint is less than that of a good white but its reflecting characteristics are somewhat different, so that it tends to lower the visibility when the airplane is viewed at certain critical angles. Of course the haze tends to lower the visibility by operating as a veil. Furthermore, as the aircraft ascends to high altitudes, the sky-background becomes less bright and the lower surfaces receive more light due to the contribution of upward light by the clouds if any are present below the airplane. Furthermore the visibility decreases somewhat owing to the decrease in the size of the image. These

FIG. 24.



Brightness (in terms of sky-brightness) of lower horizontal surface of a diffusely reflecting opaque object illuminated by light reflected upward from the earth at midday. Scale on left for two reflection factors of earth, namely 10 and 6¾ per cent. respectively. Various proportions of direct sunlight assumed and sky is uniform in brightness and equal to unity.

combined reasons account for the fairly low visibility of some ordinary aircraft at very high altitudes on very clear days. The contribution of light reflected by the earth to the lower surfaces of an airplane can be taken from this diagram and added to the values in the preceding diagrams.

A similar analysis is found in Fig. 24. The bottom scale represents a complete range of diffuse reflection-factors of the lower horizontal surface of an opaque object. Two scales on the left represent mean apparent reflection-factors of the earth, respectively 10 per cent. (at the extreme left) and 6⅔ per cent. The latter value is close to those determined for water and fields of growing crops by a vast number of photometric measurements. The region near the ordinate 0.8 represents the brightnesses of the lower surface if the best commercial flat white paints are used. As already indicated, a fair average of the sun's contribution of light directly is about 0.8, or about four times the amount of skylight when measured at low altitudes. Figs. 23 and 24, based upon photometric data, are convincing of the futility of attempting to obtain generally low visibility of airplanes as viewed from below by painting their lower surfaces white. Attention is called to the line connecting the origin with zero on the right-hand scale. This represents the condition on an overcast day. It is seen that the airplane will appear very dark against the sky for its brightness is only a few per cent. of the brightness of the sky. This and other facts yielded by the diagrams are corroborated by actual observation.

The practical solution of low visibility for airplanes as viewed from below must include means for increasing the brightness of the lower surfaces. Possibilities which suggest themselves are more diffusely transmitting fabrics and artificial illumination.

At this point it is of interest to discuss further the reasons for the low visibility of some airplanes at very high altitudes when viewed against the sky. In the absence of cirrus clouds, the sky appears much darker when viewed from a position above the earth haze whose upper surface varies in altitude usually in the neighborhood of 4000 to 6000 feet. As we ascend above this the sky usually becomes less and less bright. At very high altitudes the background against which the airplane is viewed is considerably darker than at low altitudes. This tends toward lower visibility for the airplane.

At these high altitudes the amount of light reflected or emitted upward against the lower surface of a horizontal plane approaches the amount contributed by the sky. Then if this lower surface possessed a high diffuse reflection-factor (approaching unity) its brightness, due to light directed upward, would approach the brightness of the sky. This tends toward lower visibility for the airplane at great heights. It is seen that, as the airplane approaches high altitudes, a lower value of diffuse transmission-factor will suffice to render it as bright as the sky. In fact, at high altitudes where the sun contributes a large portion of the total light, a diffusely transmitting fabric has great possibilities. An opaque reflecting surface is taxed to the extreme even at these highest altitudes.

The difference in color between the airplane and the sky (even when the former is white) is responsible partly for the visibility of airplanes at these very high altitudes. This could be overcome by means of a bluish tint in the diffusely transmitting fabric, but tinting a diffusely reflecting surface sufficiently to overcome this difference in color would lower its reflection-factor considerably so in order not to reduce the brightness of the lower surfaces of the airplane much below that of the sky, the fabric must be fairly translucent initially.

Finally, the ever-present haze which is a luminous veil tends to lower the brightness contrast and the hue contrast and thus to lower the visibility. These measurements and various other considerations lead again to the conclusion that very low visibility for airplanes viewed from below can be obtained by using highly translucent fabric of a proper tint. At extremely high altitudes where the sky is dark and the veiling haze is helpful, airplanes whose lower surfaces are coated with white or aluminum are sometimes of low visibility. At lower altitudes this certainly is not true as ordinary observation shows.

Airplane wings, consisting of two sheets of cloth separated by a distance of one to a few inches and covered with coatings such as varnish which are far from colorless, are of very low transmission-factor at present. Of course an airplane camouflaged for view from above by means of colored paints would have left none of the advantages of transparency or translucency aimed to render the airplanes invisible from below. However, two entirely distinct classes of service are in mind in considering these two opposite views. The airplane which would require low visibility from beneath would be one whose duties took it especially high so that enemies would ordinarily be beneath. But these are aspects outside the scope of the present discussion. However, from various analyses it appears that sufficient translucency can be obtained by the use of proper fabrics and varnishes. This point will be discussed later, but it is of interest to discuss the possibilities of artificial illumination. This does not appear either promising or feasible but an analysis will be worth while.

In the application of artificial light various ideas have been considered. Small lamps might be placed inside the wings between the two layers of cloth. By painting the upper sheet an initial coat of white, the effects of camouflage on the upper surfaces would be nullified if it were desirable to camouflage the same craft for low visibility as viewed both from above and from below. It might be possible to use a white translucent fabric for the upper sheet of a wing and a transparent or partially transparent fabric for the lower sheet of the same wing. There are advantages from the standpoint of efficiency of utilizing the artificial light in an enclosed space. Of course the advantages over exposed lamps are evident at once from the standpoint of head resistance. Lamps could be suspended somewhat below the wings and equipped with small reflectors; however, there are very great disadvantages in thus exposing them. The lower sides of the airplane could be studied with incandescent filament lamps or projectors could be fastened on the running gear. All of these cases of exposed lamps and equipment have the great disadvantage of increasing head resistance. High speed generators have been considered for the generating equipment and storage batteries for experimental work if the former were not available. Computations, however, do not yield encouragement.

Artificial Lighting.—Before discussing equipment some rough computations will be presented to indicate the wattage of incandescent lamps which would be required. The brightness of the sky varies usually between 0.5 to 2 lamberts, one lambert being a fair average. Assuming first that we have a perfectly diffusely reflecting white surface to be illuminated to a brightness of one lambert. The brightness of such a surface is equal to one lambert when each square foot of the surface emits 929 lumens. If the reflection-factor is equal to R, the surface must receive $929/R$ lumens per square foot. For each 100 square feet of surface painted with a white diffusely reflecting coat having a reflection-factor of 0.8 (which is about the best that could be maintained in practice) there would be required $\frac{929 \times 100}{0.8}$ lumens, or about 116,000 lumens. The rated efficiencies of the incandescent lamps used depend upon their wattage and voltage, but for this purpose it would be justifiable to operate them considerably above their normal efficiency. Assuming an efficiency of 20 lumens per watt it would require 5800 watts to supply the 116,000 lumens provided all the lumens generated were directed upon the 100 square feet of surface without loss which, of course, could not be realized. Assuming a loss of 40 per cent. it would be necessary to increase the wattage to about 9700 watts. The amount of light contributed by the earth to the under sides of the airplane depends upon the season of the year, being very high when the earth is snow covered. However, during a large portion of the year the light reflected by the earth would contribute a brightness to the lower side of the plane of the order of magnitude of 0.1 B on an overcast day (where B is the brightness of the sky), and of the order of magnitude of 0.5 B on an average clear day. Owing to the extreme variations in natural lighting these figures can be considered as being only very roughly approximate. Based on these estimates the foregoing value of 9700 watts could perhaps be reduced to about 5000 watts on an average clear day. Assuming other contributions of light to the lower sides of the airplane, this can be materially reduced in practice. The lower side of the upper plane is always brighter than the lower side of the bottom plane, due to the reflected light from the upper side of the bottom plane and also to the fact that the upper plane intercepts light which would otherwise fall on the lower plane.

The foregoing wattage estimates are for 100 square feet. The lower surfaces of airplanes are greater in area by at least three times so that the minimum estimate of 5000 watts would be increased to a total of 15,000 watts. These computations are based upon a brightness of one lambert. If the brightness of a very clear blue sky is assumed to be 0.5 lambert, the wattage required would be reduced to 7500 watts for the 300 square feet area.

It is understood that these computations are based upon certain measurements and estimates of average conditions and, therefore, aim to represent only the order of magnitude of the factors involved. It does not appear that the requirement could possibly be reduced below several thousand watts, but the generation and distribution of this wattage presents a very serious problem on ordinary airplanes. If only the very high altitudes are to be considered, it appears that the lower estimates of wattage would be sufficient.

Data on storage batteries are available and the following estimates are based upon information furnished by the Willard Storage Battery Company:

From an 80 amp-hr. automobile storage battery we obtain,
10 amperes for 8-hour discharge rate.
40 amperes for 1-hour discharge rate.
80 amperes for 20-minute discharge rate.
These are 1.5 volt cells.

The proper type of lamp can be easily obtained for any voltage but for the sake of discussion the 80-ampere discharge rate will be assumed. For 2000 watts, 25 volts would be required at the 20-minute rate. This voltage would require 6–3 cell batteries at 1.5 volts per cell. The weight is 55 lbs. per 3-cell battery or 330 lbs. for the total capacity of 2000 watts at 25 volts for 20 minutes. This weight could be materially reduced for experimental purposes because observations of only a few minutes at a time would be sufficient. It could replace the observer in a two-passenger airplane and thus the experiments might be conducted with storage batteries. However, it will be noted that the previous estimates indicate that perhaps as much as 7500 watts would be necessary in order to be practicable under certain conditions. Assuming a miniature Mazda No. 146, 18–24 volt, 1 ampere lamp, taking about 25 watts average on above battery, about 40 lamps of this type would be required per 1000 watts. The disposition of these lamps adds another difficulty to that of weight of generating equipment and air resistance, so that the realization of invisibility as viewed from below by means of artificial light appears to be a remote possibility. Color correction could be easily obtained.

A more practical generating equipment would be a high speed, 100-volt generator. The Fort Wayne Works of the General

Electric Company submitted the following weights of turbogenerators:

2 kw.	115 lbs.
3 kw.	140 lbs.
5 kw.	275 lbs.

Doubtless the weight of these could be materially reduced by using aluminum for some of the parts. The use of such turbogenerators of high speed, 3600 RPM., appears feasible for experimental work; however, a more promising and practical solution lies in giving attention to greater translucency in the fabrics and varnishes used on airplanes.

Translucent Fabrics.—There are few available data on the diffuse transmission-factors of fabrics. The data on diffusing glass convinces us that high diffusion is not incompatible with high diffuse transmission. Perfectly diffusing opal glasses have transmission-factors as high as 0.4 to 0.5. Textiles differ greatly in the transparency of the threads, silk fibres being much more transparent than cotton or linen as is seen by photomicrography. At present unbleached linen is largely being used for airplanes. This not only possesses a slightly lower diffuse transmission-factor than the bleached linen but is responsible for a yellowish tint which is undesirable owing to its high visibility against the blue sky.

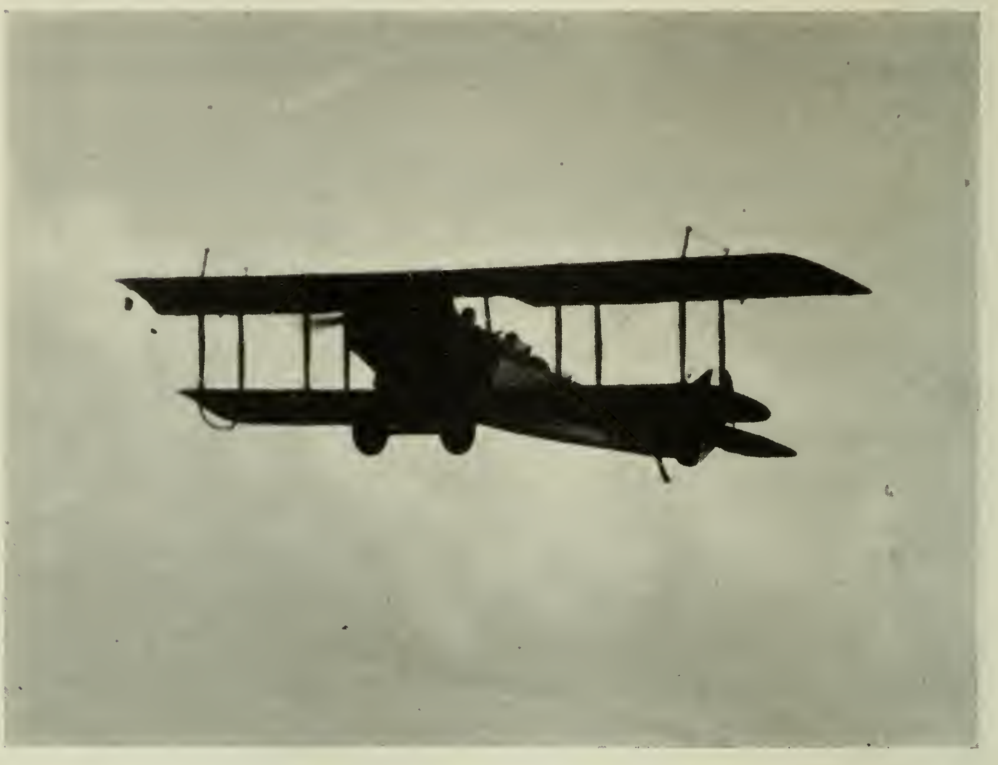
If white fabrics could be impregnated with a liquid which would render them more translucent, this would be a solution. However, bluish-white linen or cotton fabrics would contribute considerably toward low visibility if colorless varnishes were used. Measurements on prepared samples indicate that the diffuse transmission-factors of double sheets, separated somewhat as in an airplane wing, are great enough according to the diagrams (Figs. 21 to 24). If bleached linen or white cotton fabric were used with colorless dopes and varnishes, a considerable step will have been made toward low visibility as viewed from below. It is an easy matter to investigate the possibilities of fabrics after they have met the requirements as to strength.

Although photographic evidence is not as satisfactory as that afforded by direct visual observations and measurements, photographs aid in visualizing conditions described in this report. Any airplane at present is ordinarily a dark object when viewed against the sky even on a clear day. This is well illustrated in Fig. 25.

On overcast days it is very dark relative to the sky. Even though the exposure was insufficient to show the earth in its true value, the airplane appears very dark. Of course the limited contrast range obtainable by means of photography is often misleading, but this photograph illustrates a common condition.

Fig. 26 indicates the condition again except that the upper surfaces of the airplane are visible against the sunlit clouds. Even these upper surfaces which receive both sunlight and skylight are darker than the clouds. These airplanes were finished the natural yellowish white. Although the reflection-factor of this natural yellowish finish is variable and very glossy, its mean is in the neighborhood of 0.35 to 0.45. This is much less than the apparent reflection-factor of sunlit dense cumulus clouds. If bleached linen or white cotton fabrics and colorless dopes and varnishes were used the upper surfaces of the wings would be about as bright as the sunlit clouds.

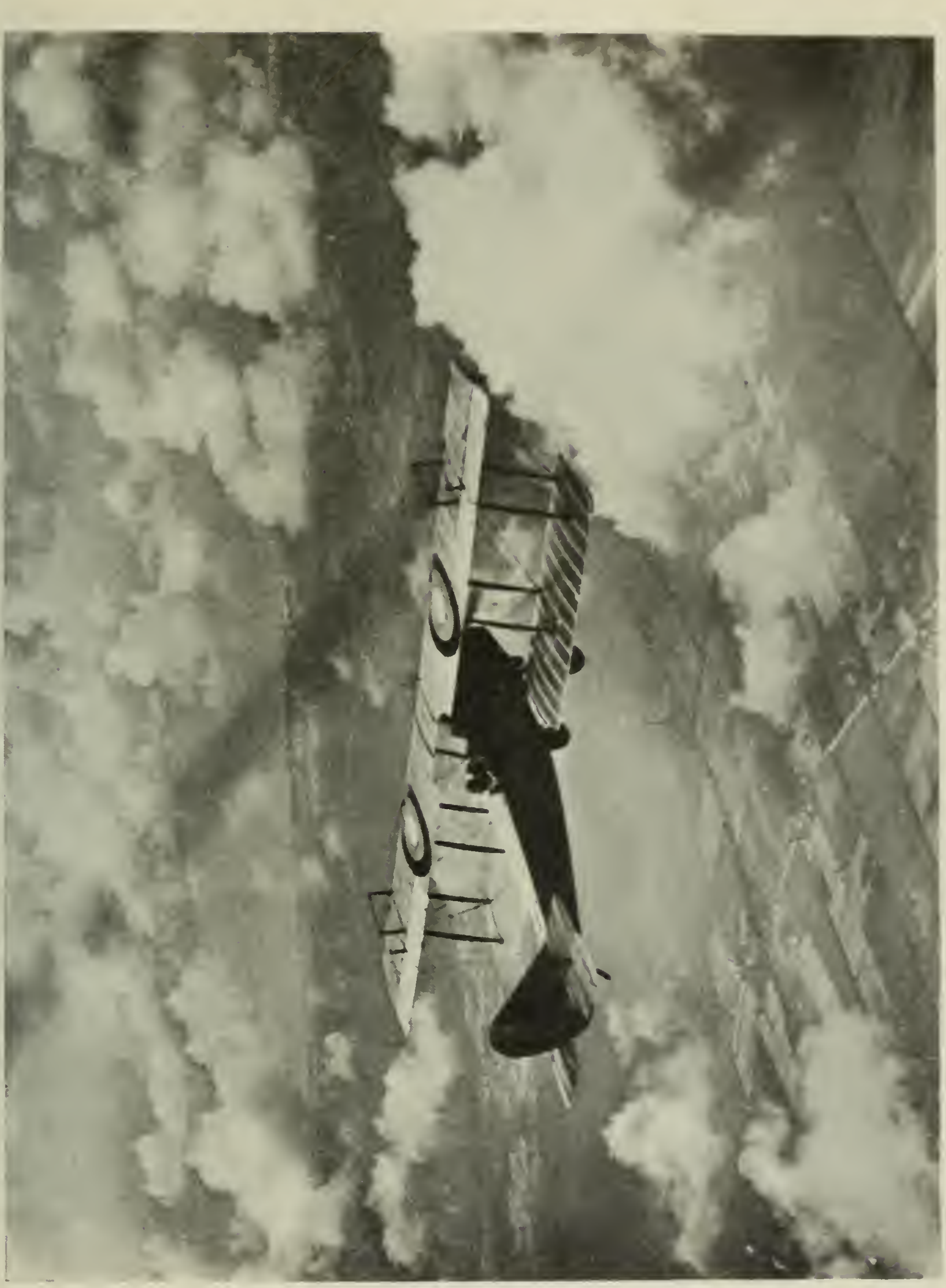
Fig. 25.



An airplane is ordinarily a dark object against the sky.

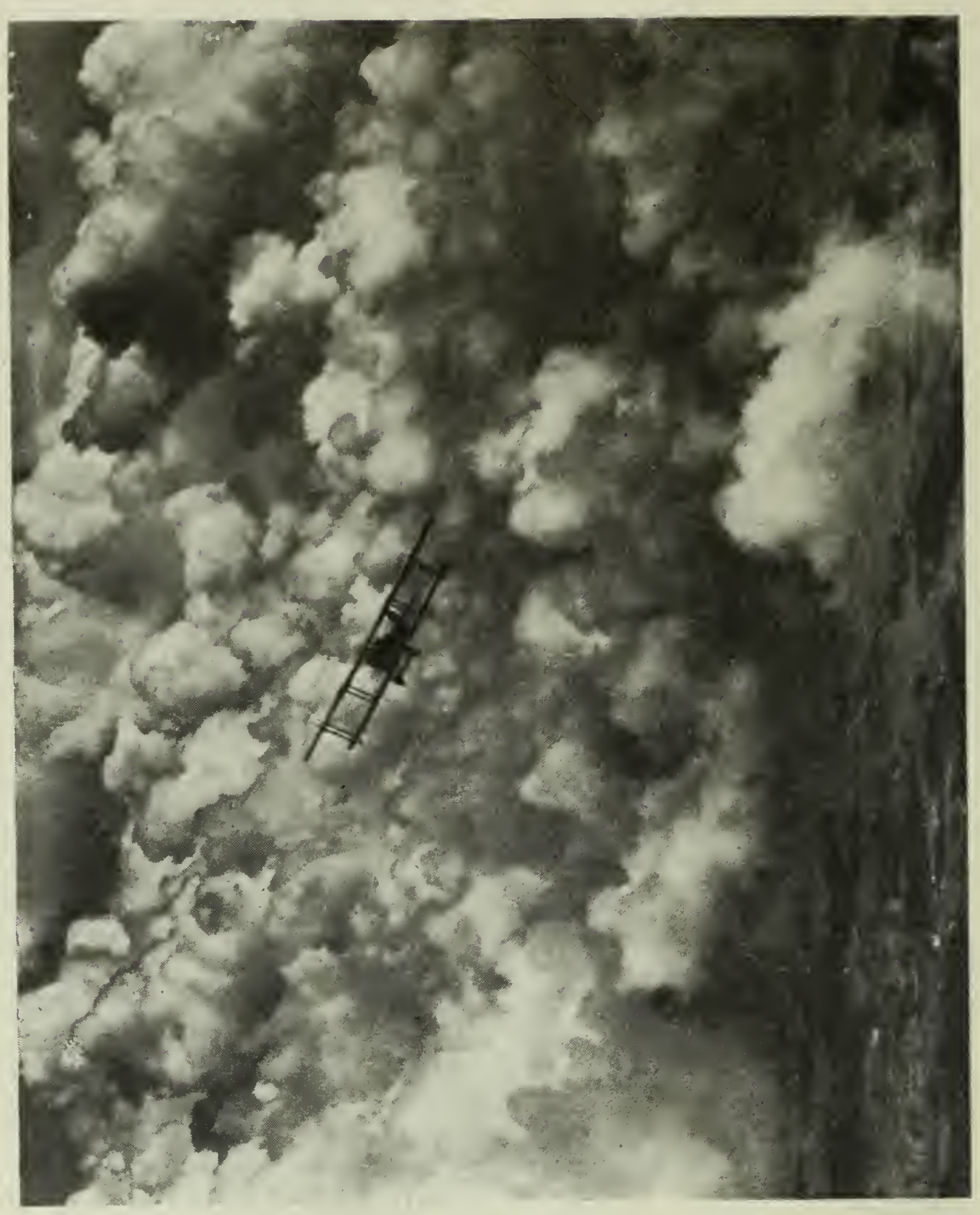
Although clouds sometimes form the background against which airplanes are viewed it is hardly practicable to consider

Fig. 26.



Airplane viewed against clouds.

FIG. 27.



Airplane viewed against a bank of cumulus clouds.

them. They are generally so overwhelmingly bright in comparison with either the sky or the earth that successful camouflage cannot be provided for both earth and cloud backgrounds on the same airplane. The same is true of sky and cloud backgrounds. Fig. 27 illustrates the variable brightness of a cloud background and again emphasizes the fact that the airplane of to-day is usually a dark object as viewed against sky and clouds.

TABLE VI.

Brightnesses of Four Samples of Airplane Fabrics (Linen) in Terms of the Brightness of Zenith Blue Sky. The Day was Cloudless with the Exception of a Few Cirrus Clouds Near the Horizon; the Zenith Sky was Deep Blue with no Suggestion of a Haze; and the Sun was at 45 Degrees Altitude. The Sky Contributed ⅙ of the Total Light Reaching the Earth. The Fabrics were Stretched Horizontally About 4 Feet Above a Large Plot of Green Grass.

Sample.	Relative Brightness.			
	No. 1	No. 2	No. 3	No. 4
One layer, upper side	7.1	4.9	3.5	6.5
One layer, lower side	3.6	2.0	1.05	3.3
Two layers (2 inches apart), upper side	6.8	5.2	3.6	5.0
Two layers (2 inches apart), lower side	1.5	0.66	0.36	1.05
Horizontal perfectly white diffusing surface	14.35	14.35	14.35	14.35
Zenith sky	1.0	1.0	1.0	1.0

TABLE VII.

Brightnesses of Four Samples of Airplane Fabrics (Linen) in Terms of Perfectly White Diffusing Surface (Horizontal) Receiving Full Sunlight and Skylight.

Sample.	Relative Brightness.			
	No. 1	No. 2	No. 3	No. 4
One layer, upper side	50	34	24	45
One layer, lower side	25	14	7	23
Two layers (2 inches apart), upper side	47	36	25	35
Two layers (2 inches apart), lower side	10	5	3	7
Horizontal perfectly white diffusing surface	100	100	100	100
Zenith sky	7	7	7	7

As an illustration of the possibilities of translucent fabrics in obtaining low visibility for airplanes as viewed from below, let us examine the results obtained with a sample of unbleached linen fabric of medium weight. A frame was supported in a horizontal plane about four feet above a grassy plot of ground by means of four thin legs. The day was cloudless, the sky was somewhat hazy but not uniform in brightness, and from the position of the experiment, practically the entire hemisphere of clear sky was visible. The altitude of the sun was about 60 degrees. The following are the relative brightnesses determined by means of a photometer:

Zenith sky	1.0
Lower side of one sheet of unbleached linen	2.3
Upper side of one sheet of unbleached linen	3.7
Lower side of two parallel sheets 2 inches apart	1.2
Upper side of two parallel sheets 2 inches apart	4.1
Upper side perfectly white diffusely reflecting surface	7.4

The relative brightness of the sky near the horizon was about 1.5, but near the sun it was many times greater as is the case on hazy days. It will be noted that the fabric when viewed against the zenith sky appeared brighter than the sky, which shows that the fabric has sufficient translucency for the purpose under consideration. If the fabric were bleached and then tinted a proper blue it would be exceedingly satisfactory on clear days provided the translucency was not impaired by the dopes and varnishes.

Data obtained for four samples on a very clear day are presented in Tables VI and VII. The zenith sky was a very dark blue and much less bright than the other portions of the sky.

17. VISIBILITY OF AIRPLANES AT NIGHT.

A white airplane may be somewhat less easily distinguished against a moonlit sky than a black airplane; however, it appears that the chief aim is to avoid being picked up by the beam of an enemy searchlight. Fundamental principles of vision convince us that a black object will become invisible sooner than a similar white object as the illumination is decreased. This is easily verified by comparing white and black objects in various positions perpendicular to the beam from an ordinary automobile headlamp.

An airplane painted a dull or matte black was sent aloft with instructions to the pilot to cross the beam of the searchlight at various heights and to hover in the extreme outer regions of the beam. When the airplane entered the more intense region of the beam it was plainly visible, but it disappeared strikingly suddenly as it passed into the less intense outskirts.

Unfortunately it was not considered feasible under the local conditions to have another airplane of regulation yellowish white finish enter the beam simultaneously with the black airplane, so it was sent aloft after the latter had landed. This airplane was more conspicuous than the black one in the intense region of the beam and was plainly visible in the outskirts of the beam where the black one could not be seen. Later only the left-hand wings of an airplane were painted black, the other wings being of the natural yellowish white. Observations on the craft sustained the former conclusions.

The result of the experiments combined with a consideration of the fundamentals of vision indicate the advisability of painting airplanes to be used at night, a matte black of best quality in order to render it more difficult for the enemy searchlights to locate them and to keep the beams directed upon them. Unless unforeseen practical considerations should mitigate against the use of the black coating, it appears that in its use there is nothing to lose but always the possibility of gain.

This argument is based upon the assumption that the searchlight is the most important consideration. Actual experience at the battlefront might modify the foregoing discussion, but from the information at hand it appears that the searchlight is the raider's primary enemy.

18. VISIBILITY OF SEAPLANES.

In Table I and in Section 9 certain data on the relative brightness of water or its apparent reflection-factor have been presented. These data are important when attempting to obtain low visibility for seaplanes as viewed against the water as a background. The mean value for inland water in Table I is 0.068. Fortunately this is of the same order of magnitude as a weighted mean of ordinary landscapes, so that a seaplane painted for low visibility over water would not be very conspicuous over a landscape except for its solid or uniform color. Pattern would not be desirable for seaplanes because areas of such size as would form the immediate background for seaplanes at various altitudes generally appear very uniform in brightness.

It would be easy to obtain a color of a proper hue by experiment, although photometric observations yield such data satisfactory to the colorist. The reflection-factor of a paint can readily be made approximately equal to 0.068. This is a very dark color and may appear to be surprisingly low in value, but the range of the mean values obtained under various conditions is seen to be from 0.044 to 0.091 in Table I for inland water. Of course individual observations were greater in value but rarely were they more than 0.1. An extremely muddy river yielded a value of 0.20, but this condition was very exceptional. The means in Table I represent a total of many hundred made on various types of days over rivers, the Chesapeake Bay, and other inland waters. The values are as a rule included in a surprisingly small range close to the mean value 0.068.

The lower surfaces of seaplanes could be coated with paints of a greater reflection-factor because they would be seen ordinarily against the distant water and sky which are generally of a higher brightness than the water viewed perpendicularly or nearly so.

The color of shallow water varies considerably, depending upon the character of the bottom, but generally possesses a dirty yellowish green color. Deep water is of a bluish green hue. Therefore a deep shade of blue-green possessing a reflection-factor of about 0.068 appears to be a generally satisfactory color if the airplane is to be viewed vertically downward over inland waters. Inasmuch as the water when viewed obliquely is considerably brighter than when viewed normal to its surface, it appears that a better compromise would be found in a paint of proper hue but with a reflection-factor in the neighborhood of 0.1 for inland-water backgrounds. As already noted the brightness of water viewed at an angle of 45 degrees is considerably greater, corresponding to a reflection-factor of about 0.15. Perhaps 0.08 would be a more satisfactory value, but this could be determined very readily by experiment. The effect of the greater relative brightness of water when viewed at the more oblique angles would be somewhat offset by the greater veiling effect of the haze at such angles. Furthermore, inasmuch as the paint would not be perfectly matte, the airplane would appear brighter when viewed obliquely than when viewed from directly above.

For this reason lower values of reflection-factor would perhaps be quite generally satisfactory.

As shown in Section 9 the relative brightness or reflection-factor of deep ocean water far from land was found to be 3.5 per cent. and for a deep channel in Chesapeake Bay near its mouth the reflection-factor averaged 4.9 per cent. when viewed perpendicularly.

19. CONFUSABILITY.

There appears to be little or no use for this type of camouflage for airplanes. Its use in marine camouflage is to confuse the submarine commander regarding the exact course, etc., of the intended victim. In aerial operations the speed is so enormously greater than in marine operations that the possibility of attaining any advantage in this manner appears very remote. It might be possible that certain gaudy or brilliant colorings would have some psychological effects upon the enemy initially, but the application of these will doubtless be more or less a matter of choice for the aviators. In order to establish the value of such patterns elaborate systematic experiments would be required with a number of observers. The value which we might hope to gain from such application does not appear sufficiently promising to warrant an extensive investigation.

An airplane covered with aluminum foil reflects direct sunlight very powerfully, which might be annoying to the enemy. When these direct reflections are absent such a plane is of low visibility under certain conditions. A disadvantage of this is the cost; however, it would appear to have the advantage of rendering the craft less inflammable.

A general disadvantage of "confusing" patterns is that the airplanes become very conspicuous. In fact, confusibility would not be obtained without conspicuity.

20. REFERENCES.

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2. "Light and Shade and Its Applications." By M. Luckiesh, 1916. D. Van Nostrand Co., N. Y.
3. "Color and Its Applications." By M. Luckiesh, 1915. D. Van Nostrand Co., N. Y.
4. "The Physical Basis of Color Technology." By M. Luckiesh. JOUR. FRANKLIN INSTITUTE, July and August, 1917.

Improved Treatment of Burns. ANON. (*Chemical and Metallurgical Engineering*, vol. xx, No. 6, p. 288, March 15, 1919.)—The war that has so recently closed has been no exception to those of the past in that all the medical and surgical arts were most intensively developed. Notable among the successes was the treatment of burns by Barthe de Sandfordt, who had spent sixteen years in trying to overcome the prejudices of the medical fraternity to his closed wax seal treatment. It was only when the hospital at Issy les Moulineaux was filled with many patients suffering with burns that it was considered advisable to depart from the usual practice and prove out this method experimentally.

The paraffine wax composition, called ambrine by de Sandfordt, is sprayed on the wound at 140–150° F., and the absorbent cotton is plied on alternately with wax layers. The aggregate of wax and cotton seals the wound and thermally insulates it as well, the temperature of the ambrine at the skin being found to be 106° F. for several hours after each 24-hour dressing. This method is actually a case of incubation, wherein the flesh and skin cells propagate themselves in a most remarkable manner. However, all infection and bacteria must be excluded if present by some such means as Dakin's hypochlorite solution with Carrel's technic, or the incubation of flesh and skin cell destroying bacteria will result, with the balance sheet showing nothing but loss. Fresh burns, being sterile, of course, are ideal for the ambrine treatment, and it has been with them that the most marvellous cures have been made.

The warm dressing has an additional virtue in that it draws the fire instantly from the wound and allows the patient to become normal. Dr. R. C. Casselberry treated the 75 employees burned at the Essington, Penna., powder explosion and reported the advantages of the ambrine treatment as: relief from pain to a great degree; cleaner and more comfortable; fewer scars and contractions; skin grafting rare; more rapid healing; superior in every way to other methods commonly used.

The army surgeons have had such marvellous success with ambrine in treating all sorts of burns that it became necessary to establish the Ambrine Laboratories, 347 Madison Avenue, New York City, to supply the demand. All manufacturing plants dealing with hot materials and having frequent burn accidents will do well to become acquainted with the results reported in the current medical literature.

THE COLOR OF WATER.*†

BY

WILDER D. BANCROFT, Ph.D.,
Professor of Physical Chemistry, Cornell University.

"Bunsen was the first to deny that water was colorless. Struck by the greenish-blue tint of the hot water of the Icelandic geysers, he poured pure water into a glass tube two meters long and blackened on the inside. He was able to detect a faint blue under these circumstances and concluded that water is actually blue. The other colors besides blue must then be due to foreign substances or to the reflection of light from a colored background. Bunsen did not go into details as to the way in which the color changes would occur. Some twenty years later, Tyndall put forward the view that the blue color of the sky is due to the scattering of light from numberless, colorless particles suspended in the air. This suggested to Soret[7] that the blue color of the Lake of Geneva might be due to similar causes and he found that the water sends out light polarized perpendicularly to the refracted rays of the sun. The analogy between the experiments of Tyndall and of Soret is so close that one may claim the existence in the water of transparent particles which may be the cause of the color. Hagenbach[8] repeated these experiments at the Lake of Lucerne, getting similar results. The following year, Tyndall[9] himself examined water from the Mediterranean and from the Lake of Geneva, sent to him in London. When a beam of light was passed through them, it became blue and the blue light was polarized. These waters are therefore not optically empty. These experiments seem to show conclusively that the water itself is colorless, contrary to the opinion of Bunsen; but this is not necessarily true. Soret himself points out that on cloudy days there was not a trace of polarization and yet the lake was blue. This is sufficient to prove that reflection is not the sole cause of the color of the water. Further, if the blue of the water were due to exactly the same

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* Communicated by the Author.

† Concluded from page 271, Vol. 187, March, 1919.

[7] *Ann. Chim. Phys.* (4) **17**, 517 (1869).

[8] *Ann. Chim. Phys.* (4) **20**, 225 (1870).

[9] *Naturforscher,* **4**, 1 (1871).

cause as the blue of the sky, the light transmitted by the water should be a crimson red at least as intense as that which lights up the tops of the high mountains or the thin clouds through which pass the rays of the rising and setting sun. This is not the case, however, as Tyndall himself points out. Also Father Secchi [10] has determined the absorption spectrum of sea-water and finds that the red and yellow are lacking. It is also well known to people who have been down in a diving-bell or who have visited the Swiss grottoes cut in the ice of the Rhone or the Grindelwald glacier that the light is bluish. There is so little red that faces appear livid.

" In 1848 H. Sainte-Claire Deville [11] analyzed a large number of natural waters and he observed that the blue waters of the Swiss and the Jura lakes, when evaporated, leave residues which are only slightly colored, while the green waters of the Doubs and the Rhine, contain a considerable amount of organic matter, so that the soluble salts were colored distinctly yellow when the water was evaporated. From this it appears that the green waters and still more the yellow or brown ones may owe their color to the presence of a small amount of yellow mud. If pure water is really blue, a small amount of yellow coloring would be sufficient to change the color to green or even to yellow. This same idea crops up again in a much later paper on the color of water by Wittstein.[12] This chemist analyzed the waters of many of the brooks, rivers and lakes of Bavaria, and thought that he had proved that the brown or yellow waters contain more organic matter and are less hard than the green waters. He explains the different shades of natural waters by assuming, with Bunsen, that pure water has a blue color, that the mineral substances dissolved in the water have no effect on the color, and that the different colors are due chiefly to dissolved organic matter. These organic substances are brown in color and are essentially humic acids. They are kept in solution by the presence in the water of a sufficient amount of alkali salts. On this hypothesis a water containing very little organic matter would be practically blue, while the blue color would change continuously to green, yellow, brown and black, as the amount of organic matter increased.

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[10] *Naturforscher*, **1**, 149 (1868).

[11] *Ann. Chim. Phys.* (3) **23**, 32 (1848).

[12] Vierteljahresschrift für praktische Pharmacie, **10**, 342 (1861).

"It is worth while to examine this hypothesis. At first sight it seems an excellent one because it rests apparently on definite facts; but it is easy to show that the hypothesis does not follow necessarily from the analytical data. It is therefore without any firm foundation and does not solve the question. I shall not stop to discuss the question whether the organic matter is brown when it is in solution or whether it becomes brown and even black during the evaporation. In view of the description of the evaporation given by Wittstein, it seems probable that the deep color is due to the action of heat.[13] Such a discussion would be a waste of time. Let us rather consider the analytical data as shown in Tables II and III.

TABLE II.
Brown waters (p.p.m.).

	Organic Matter.	KOH and NaOH.	Ratio.
Ily	37.8	10.1	3.74
Regensee	21.4	15.4	1.39
Rachelsee	43.3	18.4	2.35
Ohe	111.4	12.8	9.0
Steckenbach	55.0	9.5	3.68
Hōhenbrunnfilz	59.7	7.8	6.50

TABLE III.
Bluish-green waters (p.p.m.).

	Organic Matter.	KOH and NaOH.	Ratio.
Isaar	39.6	9.8	4.04
Brunnthaler Spring	65.6	4.7	13.97

"These figures show that the color of the waters stands in no direct relation, either to the amount of organic matter or to the alkali concentration. The green Isaar contains more organic matter than four of the brown waters and also more alkali than two of them. The waters from the Brunnthaler spring show similar relations. It is also worth noticing that Wittstein gives no analysis of a really blue water and consequently there is no real basis for a comparison. He also makes the general rule that greenish-blue waters are hard because of the small amounts of alkali which they contain while the yellow or brown waters are soft, and then he admits that the rule holds only for running water because the waters of the Lake of Starnberg are extraordinarily soft although green. I add that the blue waters of the Rhone, where the river flows out of the Lake of Geneva, are also soft, as is shown by the large number of laundries along the river. It is evident that the color is not different for running and for stationary waters. Wittstein's hypothesis therefore seems insufficient. It may be true, however, for some very deeply-colored waters because if these really hold a colored material in solution or in suspension, their color ought to be dark.

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[13] During the evaporation insoluble brown flocks form and become even darker. If heat changes the solubility of the organic matter, it may also affect the color.

" Schleinitz [14] attributes the change in the color of sea-water to the greater or lesser amount of dissolved salts. He noticed sudden changes in the color of the sea when he was crossing from Ascension towards the Congo on board the *Gazelle* in 1875. On August 23, 5° south latitude and 9° west longitude, the sea changed from blue to greenish. On the twenty-fifth it was bluish and on the twenty-sixth in 5.5° south latitude and 5.5° west longitude, the sea became again deep green, changing to a dirty green and then to a brown as the ship approached the Congo. Later, on the voyage from the Congo to the Cape, the sea became green, then bluish-green, and finally bright blue. Each time that the sea became greenish Schleinitz found that its specific gravity decreased while there was an increase when the sea became blue again. From this he concluded that the bluest water contained the most salt and that the salt was the cause of the color. Although this observation led to a false conclusion, it confirms some of the results which I have found and I shall come back to it again.

" It is worth noting that in the waters of the Lake of Neufchatel and also in the ice from the lake, J. Brun [15] found an alga which is green, orange, red, or brown, depending on the different phases of its development, and turns black after death. Its presence might well affect the color of the water."

In order to determine the color of pure water Spring took two tubes five metres long and about four centimetres inside diameter, coated with black on the outside. When distilled water from the laboratory supply was put into the tubes, the color was a light green very like that of a dilute ferrous sulphate solution. Some days later the tubes were filled with freshly-distilled water and the color was a fairly pure sky-blue. After standing about seventy hours in the tubes this water was as green as the first without having lost anything of its clearness. This preliminary experiment shows that the distilled water of the laboratory is far from being pure and contains substances which undergo changes, in that a blue water becomes green slowly. These foreign substances may be inorganic or organic; it is not impossible that they are living organisms. The following experiment is evidence in favor of this. "The two tubes were filled with distilled water but one ten-thousandth of mercuric chloride was added to one tube. At first both tubes were blue and there was no perceptible difference between them. After six days the water in one tube had become green, while the water containing the mercuric chloride had not changed in color, and even after three weeks the blue color was the same. Mercuric chloride was then added to the green tube and after three days a distinct change towards blue was noticeable. At the end of nine days no further change took place and the water was distinctly bluish-green; but it never returned to a pure blue. Since mercuric chloride is one of the most toxic substances known, especially for minute organisms, there is certainly reason to believe that living organisms are to be found in the distilled water of the laboratory and that the water also contains the food necessary for the development of these organisms. . . .

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[14] *Naturforscher*, **8**, 59 (1875).

[15] Jahresbericht über Chemie, **1880**, 1512.

" Stas[16] has shown that rain water or spring water, if distilled twice, gives a liquid which volatilizes without leaving any residue if evaporated at once in a platinum vessel. If this same distilled water is kept several days and then evaporated, it leaves a noticeable brownish-yellow residue, which burns completely at red heat in the air. Stas concluded that distilled water contains volatile organic matter which becomes non-volatile spontaneously in the course of a few days. This conclusion fits in well with my observations. So long as the distilled water contains the dissolved organic matter in a volatile state, the water is blue by transmitted light, but it becomes more and more green as the dissolved matter becomes changed by the action of organisms and ceases to be volatile. A similar fact has also been observed by P. Glan[17] in his studies on the absorption of light. He calls attention to the difficulties due to the presence of foreign matter which it is almost impossible to remove. He notes that after distilled water has stood several days in a closed vessel, it lets less light through and appears as though turbid.

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[16] Bull. Acad. roy. belg. (2) 10, (1860).

"These preliminary experiments show that the distilled water of the laboratory is absolutely unfit for experiments like these, for it changes on standing. Stas[18] has pointed out a method for obtaining pure distilled water. It consists in distilling spring water with a mixture of manganate and permanganate of potash, taking care to condense the vapor in a platinum cooler. Water prepared by this method contains no trace of non-volatile organic matter either when first distilled or later. I have made use of this method, taking all sorts of precautions. Ordinary water was first boiled with alkaline permanganate for four hours in a glass vessel. It was then distilled twice in an apparatus made entirely of platinum and was collected in a closed silver flask out of contact with the air. In order to clean the apparatus, three litres of water were distilled and thrown away. Then the first fifth of the final amount of water distilled was used to wash the surface of the silver flask. I have satisfied myself that water thus prepared is volatile without residue. To show this I have polished the inside of a platinum crucible with precipitated and dried silica so as to get a brilliant surface on which the least trace of residue would show. When the water was evaporated in this closed crucible, no visible deposit could be detected on the mirror surface, and I believe that one cannot say that such water contains any non-volatile material.

"When this pure water was poured into the tubes it is hard to describe the purity of the blue color which was seen. The only thing that could be compared to it is the most beautiful blue of the sky on a clear day at the top of a high mountain when one is far above the mists rising from the ground. When the tubes were allowed to stand for two weeks, no change in the purity of the blue could be detected. This permanence of color is perhaps a proof of the extreme purity of the water. I have tested this water by the Tyndall method, focussing a magnesium flame on one point in the tube by means of a concave mirror. Unless my imperfect apparatus has led me into error, the luminous cone was scarcely visible in the liquid. It was difficult for me to say whether its path could be detected or not. Whatever one may think on this point, it appears certain that the purest water which one can prepare is a wonderful blue if one looks through a sufficiently thick layer. Is this color peculiar to the water or is it due to a reflection of the incident light as is the case with the blue of the sky? I think that everybody will reject any hypothesis as to the color being fortuitous. Under the conditions as arranged, one looked through the water along the axis of the tubes in the direction of the illuminating ray. If the blue were due to the reflection of light from otherwise invisible particles, the maximum intensity of the blue color should be found in a direction perpendicular to the luminous ray, which is just the opposite to what occurs actually. Further, on this assumption the transmitted light ought to be red or mixed with red, which is not the case, the purity of the blue proving the absence of red. In addition I have made another experiment which seems to me conclusive. If the blue color of water is not characteristic of this substance and if it is due to the presence of foreign matter coming from the air, it follows that any liquid would be blue like the water if treated in the same way. In other words, there could be no colorless liquid. I have distilled five litres of amyl alcohol for several weeks in a glass vessel and exposed to the air of the laboratory. In spite of this careless treatment and in spite of the fact that the liquid had taken up a good deal of dust, there was no sign of color in the tube when the layer was five metres in thickness. Lack of material prevented an examination of a layer ten metres in thickness.

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[17] Pogg. Ann. **141**, 66 (1870).

[18] Mém. Acad. roy. belg. **35**, 110 (1865).

"At first I tried crystallized acetic acid and absolute ethyl alcohol, but these substances were yellow when examined in a five-metre layer. This yellow color disappeared gradually as the layer was made thinner without showing either green or blue. I am not certain, however, that these substances are really yellow because acetic acid and ethyl alcohol are apt to contain empyreumatic substances which are very difficult to remove. It seems certain from these experiments that the purest water one can prepare is not colorless but has a blue color due to an absorption in the yellow and not to a reflection of the incident light.

"We can now discuss the causes of the different colors of natural waters. Since analysis has not shown in any definite way the presence of green, yellow or brown matter in the green waters, and since Wittstein himself admitted the absence of any yellow mud in the green water of the Lake of Starnberg, a different line of attack must be chosen. Five litres of pure, blue water were treated with a few grams of a lime containing no iron and obtained by calcining Carrara marble. This lime water was quite clear after standing for five days. A solution of carbon dioxide in water was added until a precipitate was just barely visible. When placed in the tubes the water was then absolutely opaque. It would not have been any different if ink had been poured into the tube instead of this calcareous water. The water was taken out of the tube, diluted with pure water, and treated with carbon dioxide to precipitate the calcium carbonate and then to redissolve it as bicarbonate. Every now and then the current of carbonic acid gas was cut off and the water was examined in the tubes. The original opacity disappeared slowly and the light which came through was first brown, then pale brown, yellow, green, and finally the liquid became blue again though with a touch of green after the carbonic acid had been run in for eighteen hours. With the combined action of carbon dioxide and calcium carbonate it is thus possible to reproduce all the colors of natural waters from complete opacity to a greenish-blue.

" As a further confirmation I have prepared a saturated solution of calcium carbonate and carbon dioxide in pure water, which was green when viewed through a five-metre layer. I then placed this in a vacuum to draw off some of the carbon dioxide and to cause a dissociation of the bicarbonate, after which the liquid was examined in the tube. Each time this was done, the color became more yellow. The green disappeared soon and finally the tube became opaque. A drop of hydrochloric acid brought back the greenish-blue color. Similar results were obtained with barium hydroxide and carbon dioxide. With excess of the latter the water became brown, yellow, green and bluish-green. Using hydrochloric or nitric acid instead of carbon doixide the color changes are obtained more rapidly. A solution of sodium silicate containing a little free silicic acid was opaque in a five-metre layer and brownish-yellow when a metre in thickness. When a concentrated solution of caustic soda was added to dissolve the free silicic acid, the yellow color disappeared. Pure water holding in suspension a little amorphous silver chloride is opaque or yellow, depending on the thickness of the layer. Ammonia dissolves the precipitate and removes the opacity or the yellow color.

"These experiments warrant the drawing of several conclusions. A luminous beam of given intensity will not pass through a sufficiently thick layer of a liquid holding enough particles in suspension even though these are transparent or colorless. A tube containing suspended calcium carbonate, barium carbonate, silica or silver chloride may be opaque to diffused daylight and yet let through light from the sun or from burning magnesium. The physical state of the suspended particles does not affect the phenomenon. If one pours water into ethyl alcohol containing a little dissolved amyl alcohol, a persistent turbidity is caused, due to the minute drops of amyl alcohol which do not dissolve in the water. By varying the amounts of ethyl alcohol and water for a given amount of amyl alcohol, one can change the degree of turbidity and make it as small as one pleases. It is evident that each drop of amyl alcohol is liquid and transparent, and yet such a turbid liquid is opaque for a definite thickness of layer and intensity of light; it is yellow if the light is more intense and colorless under a very powerful light. Similar changes take place if the intensity of the light is kept constant and the thickness of the layer decreases. The reason for this is easy to see. When a ray of white light passes through a medium which holds in suspension an infinity of reflectors, each simple wave forming the white light is reflected independently of the others. If there is not total reflection the intensity of each wave will decrease with increasing thickness of the layer. Since the different colors constituting white light have not the same luminous intensity, the weakest will disappear first and the color at the ends of the spectrum, the red and the violet, will be eliminated early while the yellow, which is the most intense to our eyes, will outlast the others though weakened itself. One could probably explain the phenomenon in another way and say that when white light passes through an absorbing medium the yellow is the last to disappear.

"I will add that it is not necessary to have a liquid holding reflecting particles in suspension. A similar phenomenon occurs in the air. Everybody has noticed that the shadow projected by smoke or by condensing vapor on a white background is not merely gray; it always has a yellow-brown color to which one gives the name of yellow smoke or brown smoke. A liquid holding a colorless substance in suspension appears white solely because of the reflected light. Milky lime water, though very white, is as opaque as ink, and the white color shows merely that the light which illuminates it does not pass through it.

"There is still another point which calls for attention. If the yellow color of a liquid is due to the suspension of a certain number of solid or liquid particles, the color should disappear as the particles sink; it should be ephemeral. If this were true, the suggested explanation of the different colors of natural waters would present a real difficulty; but this is not the case. I have allowed a turbid lime-water solution to stand for seventeen days in the observation tubes. At first no light came through, but after some time the lime began to precipitate in the tube and the liquid became more and more green. At the end of twelve days the water was so clear that one could see through the tube a light pencil mark on a piece of paper. The color of the water was green, nevertheless, and remained so. It was evident that I was dealing with a solution of lime in water without any real suspension of solid matter, and yet there was enough yellow left to form a green with the blue of the water. Turbid waters containing bicarbonate of calcium or of barium in suspension show the same phenomenon, whence it follows that the resistance to the passage of light manifests itself also when light passes through saturated solutions where a precipitate is ready to form. This last might be called a nascent precipitate by analogy with the nascent clouds which Tyndall has taught us to recognize. To test this point experimentally, I have made at 18° a nearly saturated solution of pure calcium chloride containing no iron. In the observation tube this solution was a beautiful greenish-yellow. When diluted with water or when the thickness of the layer was decreased, the green became more marked. An almost saturated solution of pure magnesium chloride has shown a very pure golden yellow. A saturated solution of equally pure sodium chloride was wonderfully transparent and had a magnificent chrome-green color. I have not examined solutions of other salts because of the difficulty of getting them really free from iron. I believe nevertheless that it is proved that the yellow color produced by dissolving a salt depends less on the amount of salt dissolved than on the nearness of the solution to the crystallization point. Small amounts of a slightly soluble salt will produce the same effect as large amounts of a more soluble substance. To test this directly, I boiled pure, blue, distilled water for some time in a glass flask. It is known that glass is slightly soluble in water. When the cooled water was poured into the observation tube, it proved to be completely opaque. After some hours a deep yellow light passed and at the end of two days it became green and remained so. Its clearness was then very great, but the small amount of transparent material which had been taken from the glass was enough to color it green.

"We can now show how the observed facts may be used to account for the colors of natural waters. We start with the assumption that a sufficiently thick layer of absolutely pure water has a beautiful blue color. If small amounts of colorless salts are in true solution, the color of the water will remain blue; but if the water contains greater or lesser amounts of a nascent precipitate the light passing through the water will be a more or less deep yellow. There may even come a point at which no light will pass and the liquid will appear opaque; in other words, black. The yellow light will necessarily blend with the blue of the water to form a series of tints which will vary with the amount of yellow from greenish-blue through bluish-green to green. If there is too much yellow, the blue will disappear and the water will be a brown-yellow or even darker.

"Let us see now how these conditions may be realized in nature. The sparingly soluble substances in the natural waters, which may appear as nascent precipitates, are for the most part calcium carbonate, magnesium carbonate, silica, aluminum silicate or alumina. It is not necessary to consider the more soluble substances such as the chlorides and sulphates of sodium and magnesium because they do not occur in sufficient quantities to produce the effects in question. A blue water like the Lake of Geneva, or, better, like the Lake of Achen in the Tyrol, must have the calcareous matter more completely dissolved the more blue the water is. There must therefore be a sufficient amount of carbon dioxide to form calcium bicarbonate. A green water, on the other hand, like that of the Lake of Constance, must have the calcareous matter in a less perfect state of solution, which must be due to there being relatively less carbon dioxide in the water. It is interesting to note that these predictions are verified. In 1848 Sainte-Claire Deville analyzed the green water of the

Rhine at Strassburg and the blue waters of the Rhone at Geneva, determining also the dissolved carbon dioxide.[19] The data which interest us are given in Table IV. When referred to a constant quantity of calcium carbonate there is relatively nearly twice as much carbonic dioxide in the waters of the Rhone as in those of the Rhine. The calcareous matter is therefore dissolved more completely in the former case and, as a matter of fact, the waters of the Rhone are blue.

"If it is true that, when other things are equal, a calcareous water is more blue the more completely the calcareous matter is dissolved, it ought to be possible to make a blue water green by bringing it in contact with lime-stone. The free carbon dioxide would then be converted completely into calcium bicarbonate. In the Lake of Achen the water is a deep blue out in the lake and a most beautiful chrome-green along the northern shore where the water is shallow and the bottom consists of lime-stone pebbles from which the waves grind off invisible particles of calcium carbonate, thus causing a change of color. The greenish tones of shoals at sea and along the edges of lakes are probably due to the same thing. The sands of the sea contain fragments of crushed shells and the lands along the shores of the lakes are usually sufficiently calcareous to saturate part of the carbon dioxide in the water.

TABLE IV.
(*p. p. m.*).

	Rhine.	Rhone.
Calcium carbonate	135.6	78.9
Free carbon dioxide	7.6	7.95

"So far we have considered only the calcareous matter; but silica and alumina can produce the same effect. A green water might contain no trace of calcareous matter, in which case the silica or alumina would have to produce the color. Would a water containing alumina and silica give different tints and would it be possible to remove the alumina in any simple and natural way? The answer to this is easy. We know that clay or aluminum silicate forms a pseudo-solution in water though not soluble in the true sense of the word. The water of a river flowing over a fat, clayey mud, does not become completely clear on standing. Although the clay is not dissolved, it acts as though emulsified in the liquid. If one adds to the water a solution of a salt, such as sodium chloride, the aluminum silicate precipitates rapidly. This may be observed on an enormous scale at the mouths of large rivers. Their waters remain turbid even though the current has almost disappeared, so long as they do not mix with the sea-water. When this happens, the mud settles rapidly and this accounts for the formation of those deltas which are built up grain by grain and yet finally dam the river which formed them and force it to change its course. When the alumina precipitates the water becomes blue again. Reference has been made to the observations of Schleinitz on board the *Gazelle* as to the sudden changes in the color of the sea. He noticed that there was an increase in the density of the water when the blue color reappeared and he therefore concluded that the blue color was due to the salt. The real explanation is that the salt precipitates the aluminum silicate, which had caused the green color, when present in suspension in the water.

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[19] It is surprising that these two analyses are the only ones given in the chemical literature. Are there no others?

" One other point may be raised. Is it not possible that the polarization of the light observed by Hagenbach and by Soret in the Swiss lakes was due to the reflections which produce the yellow color rather than to reflections producing the blue color?"

While denying that suspended particles are the cause of the blue color of water, Spring[20] recognizes the important part which they play in the color phenomena.

" One might think that the blue color of water would be sufficient in itself to account for the blue color of the Atlantic, the Mediterranean, and certain lakes; but this is not so. The action of water on the different components of white light varies very much. It absorbs the red strongly even in thin layers but it absorbs the other colors to some extent. If one were to examine the solar spectrum after sunlight has passed through an ever-increasing thickness of pure water, one would find the red, the orange, the yellow and the green disappearing successively and finally the blue when the thickness of the layer was sufficient. The light of the sun would therefore be absorbed completely in absolutely pure water if the water were deep enough. Such water would therefore appear as black as ink. Can such a depth of water be realized in nature? Some years ago Fol and Sarasin[21] made some new experiments to complete work begun by Fol and others, in which they showed that daylight does not penetrate more than two hundred metres into the waters of the Lake of Geneva even in calm weather and in the month of August. They proved this by lowering to different depths in the lake a special apparatus containing photographic dry plates with a rapid bromide emulsion made by our countryman Van Monckhoven. Those plates which were lowered 237–300 metres showed no effect of light when developed, whereas at 170 metres the illumination was apparently about equivalent to that on a clear but moonless night.

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[20] Bull. Acad. roy. belg. (3) **12**, 814 (1886).

"Depths of more than two hundred metres are the rule not only in the ocean but also in most lakes. Consequently these deep waters, from which the light should never return, ought to appear absolutely black to us. Their surface might send back some reflected rays just as ink will; but the mass of the liquid ought not to appear colored if it sends back no light. Along the shores and in the shallows the blue color might show because the conditions would be more or less favorable for the daylight being reflected to the eye. The real phenomenon is quite different. The deepest waters are the bluest and in the shallow waters the blue gives way to green or even to yellowish-green and brown. How are we to account for this? . . .

"Tyndall has shown that no natural water is optically empty. Even after standing a long time the water of the Mediterranean and that of the Lake of Geneva scatters a beam of light. We therefore see the natural blue of certain seas and certain lakes because the daylight does not penetrate far enough into them to be absorbed completely. It encounters myriads of particles of foreign substances which reflect it in all directions like a multitude of microscopic mirrors. The effect to the observer is the same as though he were looking through a very thick layer. From this it follows that in a very deep and very clear lake containing relatively few suspended particles, a beam of light would penetrate further than into a more turbid water before all the rays would be reflected back. This clearer water would be a deeper blue and we find actually that the dark blue waters emit less light. It is also easy to explain the variations in the quality and intensity of these waters with sky changes or with varying agitation of the surface. . . .

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[21] Comptes rendus, **100,** 991 (1885).

"If the suspended particles are relatively numerous, a beam of incident light will not be reflected often in the water before melting the particle which will send it out. The blue will therefore not be saturated and will contain much white light. If the particles are few and far between, the beam will pass through a longer route in the water and the effect will be the same as though the observer were looking through a greater thickness. The blue will be more saturated and a deeper shade. In consequence of these multiple reflections the apparent illumination of the water does not necessarily come from a very great depth. The phenomenon is like that observed by all tourists in the mountains who have crossed freshly-fallen fields of snow consisting of the original small crystals which have not yet agglomerated to larger grains. Each hole made by sinking the point of the ice-axe in this snow is illuminated by the most beautiful blue light. This blue does not come from the depths of the ice or the snow but is due to the fact that a ray of white light has been reflected a million times more or less from the surfaces of the little snow crystals before reaching the eye of the tourist. At each one of these reflections from a blue substance it has lost some of the reddish light and consequently appears more and more blue. This explains why the waters of some mountain torrents are a beautiful blue, the intensity of which seems out of proportion to the depth of the water. The Ticino gives a series of illustrations of this between Airolo and Bellinzona. This explains why a light object, like an oar for instance, appears blue when plunged a little way into the water of a blue lake, even though the layer of water covering it is not itself sufficient to show the blue. The light reflected back by the object has not only traversed the slight depth between it and the surface, but comes also by reflection from the sides and is therefore blue.

"If the lateral distances are not sufficient, as is often the case near the shores of a lake or a sea, the phenomenon becomes complicated. The light coming from these points will necessarily be less saturated with blue even though the bottom is white. Since water absorbs most readily the least refrangible or red rays, and then the others less and less completely up to the blue rays, the less refrangible rays will not be cut off in a thin layer of water and the light will appear green. This is probably the reason that the waves of the blue sea appear green. One really sees them by light transmitted through a relatively thin layer."

In a later paper Spring[22] points out that an optically empty water may appear blue when seen from above if the temperature of the liquid is not homogeneous. A column of water unequally heated is equivalent to a light fog if the tube is short and to a dense black cloud if the tube is long enough. "The light is reflected and refracted from the layers of unequal density and is scattered irregularly in all directions as though the liquid contained infinitely small particles. In other words, such a medium does not behave like an optically empty one. This is important for the illumination of clear natural waters. A lake of pure water will appear blue if there are convection currents in it. The presence of solid particles is not absolutely necessary. If the convection currents are infrequent the lake will appear much darker, even though there has been no change in the chemical composition of the water. This is true experimentally. Forel[23] points out that the soft-water lakes are more transparent in winter than in summer. This is because in summer there is a greater difference between the temperatures at the surface and in the depths. In consequence of agitation due to many causes, the layers of water of different density do not remain stratified one above the other in a regular manner. They mix and convection currents are produced in all sorts of directions scattering the light every which way. Forel has observed that during the summer months it is absolutely impossible to see the bottom and to detect the ancient objects which one looks for in the ruins of the lacustrine cities at depths of 3–6 metres. In the winter the water is usually transparent enough to make the search profitable."

Special experiments showed that in a tube twenty-six metres long a difference of 0.57° between the water in the tube and the surrounding medium is enough to produce opacity. "This slight difference is quite within the order of temperature variations which must occur inevitably in the waters of lakes and seas. It makes us see that the tint cannot be the same in the zones exposed to the sun's rays and in the zones situated in the shadow of a cloud or a mountain. The water which receives the rays of the sun must appear more luminous not merely because of the greater amount of light which falls upon it but also because the solar energy makes the water less transparent than that in the shade. If the wind blows unevenly over the surface of the water, differences of the same order may be noted. The wind causes evaporation which lowers the temperature of the water, thus neutralizing the convection currents due to the heating by the sun's rays, and making the water appear more transparent, or less illuminated. This accounts for the difference in tints to be noticed on the surface of lakes and seas, differences which indicate to some extent the direction of the wind."

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[22] Bull. Acad. roy. belg. (3) **31**, 94, 256 (1896).

[23] Arch. Sci. phys. nat. **59** (1877).

TABLE V.

Fe_2O_3	Color.
1 : 10 000	Dark mahogany brown
1 : 100 000	Deep yellow
1 : 1 000 000	Yellow
1 : 2 000 000	Golden yellow
1 : 4 000 000	Yellow with trace of green
1 : 6 000 000	More yellow than green
1 : 8 000 000	Grass green
1 : 10 000 000	Green with trace of blue
1 : 12 000 000	Bluish-green
1 : 18 000 000	Greenish-blue
1 : 20 000 000	Blue with trace of green
1 : 24 000 000	Blue like pure water

In still another paper Spring[24] takes up the question of colored compounds in the water, especially iron and humus. He determined the color of pure water containing varying amounts of ferric oxide in solution or suspension. He did this by dissolving in aqua regia 0.700 g. iron which is equivalent to 1 g. of Fe_2O_3. After this had been evaporated to dryness on the water-bath, the product was dissolved in one litre of pure water distilled in a platinum apparatus. This yellow-brown solution was then diluted and examined after dilution in a tube five metres long. The data are given in Table V.

" From this it follows that ferric oxide affects the blue color so soon as its concentration gets above one part in twenty-four millions. On the other hand, the Lake of Geneva contains one part of ferric oxide in about three million, but the water is blue and not yellow. The water of the Meuse is green and not yellow when it contains one part of ferric oxide in 1,500,000 of water. On the basis of analysis the Mediterranean should be brownish-yellow and not blue. From this it follows that the iron in these waters is not present in the same state as when a solution is made up in the laboratory. The point that has been overlooked is the effect of humic matter. . . .

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[24] Bull. Acad. roy. belg. (3) 31 578 (1897).

" In order to get suitable humic matter I have taken the black waters from the peat bog on the plateau of Baraque Michel, which is the highest plateau in Belgium. In this way I was certain of getting water uncontaminated by industrial products and containing only the brown-black compounds dissolved from the peat. It is therefore probable that the substances used corresponded closely and perhaps absolutely with the humic matter found in so-called pure, natural waters. In fact the water I used was black as ink by reflected light but somewhat coffee-brown by transmitted light when observed in a twenty-centimetre layer. It can be filtered through filter paper, though very slowly, which proves that the brown substance is not entirely in solution. Its density was 0.99885 at 25.5°. Since pure water has a density of 0.99759 the peat water was 1.0012 times as dense. When examined with a spectroscope it gave a continuous, dark spectrum, in which one saw only red and green, but no blue and almost no yellow. It had a slight acid reaction. When evaporated in a platinum crucible, it left a black residue of 0.152 g. per litre. After the carbonaceous matter had been destroyed by heating in the air the residue weighed 0.0238 g. There were therefore 0.1282 g. of organic combustible matter per litre of water. The small content of mineral matter (0.0238 g./litre) indicated a water that has not flowed far through the earth. It is actually rain-water filtered slowly through a layer of peat.

" With this peat water the effect of humic matter on the color of water has been determined. The data are given in Table VI, the concentrations being grams of combustible matter per gram of water.

" This table shows the extreme coloring power of humic matter. It has an effect about double that of ferric oxide if one compares equal weights. It is therefore easy to see the difficulties to be surmounted in a laboratory preparation of a really blue water, a pure water not containing more than one part in fifty million of organic matter.

"Filtered water from the Meuse contains about one gram of combustible matter in nine thousand of water. If the combustible matter in the water of the Meuse were brown, soluble, humic material like that of the peat water, the river should look like a river of ink. The organic matter of the natural waters can no more be dissolved humic matter than the ferric compounds can be in a true state of solution. The concentration is more than a thousand times that which corresponds to the actual color of the water.

Table VI.

Humic Matter.	Color.
1 : 500 000	Yellow-brown
1 : 1 000 000	Yellow
1 : 10 000 000	Yellowish-green
1 : 20 000 000	Green
1 : 30 000 000	Bluish-green
1 : 40 000 000	Greenish-blue
1 : 50 000 000	Blue

"From the preceding results one might expect to get a very dark brown liquid by mixing water containing a ferric salt with water containing humic material; but this is not the case. The water clears up and the rate of clearing is faster the more intense the light. . . . Under the influence of light the organic matter reduces the ferric salts to some extent, converting them into green ferrous compounds, the coloring effect of which is not comparable with that of the ferric compounds. Owing to the absorbed oxygen the humic matter probably becomes more acid and therefore forms salts more readily with the oxides of iron, alumina, etc., these [hypothetical] salts precipitating readily on account of their insolubility. The ferrous compounds remaining in solution are oxidied by the action of the air or by the oxygen dissolved in the water. When converted into ferric compounds they oxidize more of the unprecipitated organic matter. The ferric compounds therefore act in natural waters in the way hæmoglobin does in the blood of animals. . . . Hæmoglobin is looked upon as an oxygen carrier, taking it up from the lungs and distributing it through the system. The organic substances in the water are immersed in a medium which burns them while the body of an animal is irrigated by an oxidizing liquid.

"The interaction of ferric salts and organic substances under the influence of light gives rise to an apparent equilibrium between the oxygen of the air and the ferrous compounds. If the intensity of the light increases, the proportion of ferric compounds decreases, because the organic substances will be oxidized more completely. Since the water will then contain smaller amounts of yellow or brown compounds, it will become more and more distinctly blue. On the other hand if the intensity of the light decreases, the rate of the oxidation will decrease and the water will become more and more green, or even yellow, because the supply of coloring matter will not fall off with decreasing intensity of light. It is therefore easy to see why waters exposed to the sun are usually the bluest.

"If the amount of iron is very small relatively to that of the humic substances, these latter may be oxidized very slowly, in which case they will impart their brown, or even black, tint to the waters in which they are. The black waters of the equatorial regions of South America are said [25] to contain 0.028 grams of *free humic acids* per litre, a little more than one-fifth as much as the *black* peat water from the plateau of Baraque Michel in Belgium. In his paper on the color of water, Wittstein [26] has pointed out that the brown waters of Bavaria are remarkable for their softness. They contain almost no mineral matter.

"If the amount of iron is relatively large, there may be almost complete elimination of the organic matter. Almen [27] has called attention to the purity of the great lakes of Sweden. Lake Wettern is almost free from organic matter. Between these extremes there are the more common cases where the waters contain iron and organic substances in what one may call ordinary amounts: If one omits the instances where these waters are obviously turbid, their color will be a dark green like those of most of our rivers, the Meuse, for instance, the waters of which are characterized by the absence of depth of color and by a lack of that transparency which one finds in lakes or in the ocean. This is the effect that would be produced by the joint presence of iron and of organic substances.

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[25] Muntz and Marcano: Comptes rendus, **107**, 231 (1888).

[26] Vierteljahresschrift prakt. Pharmacie, **10**, 346 (1861).

[27] Ber. deutsch. chem. Ges. **4**, 750 (1871).

" In so far as the waters of the river are exposed to the sunlight, a purification is continually taking place. If the river is sufficiently long, the purification may even be complete before the waters reach the sea. This happens with the Nile. The upper waters are green in the dry season and become more and more blue as one approaches the mouth of the river. In this case one can exclude the hypothesis of the change of color being due to the influx of other waters. It is the water of the Nile itself which changes color as it flows to the sea.

" In this way one can account for the deep blue color of the high seas and in general of large masses of water, even when the analysis does not permit us to recognize any important differences. The ease with which humic matters combine with ferric oxide makes it clear why ferruginous mineral deposits always contain organic matter. In fact, the limonites of the prairies and the ochres have been suggested as raw material for making humic compounds."

The green often observed in swimming pools is undoubtedly due to suspended matter, though I can find no record of anybody having determined the exact nature of the suspended matter.

A special point has been discussed by Steuer.[28] "The color and the transparency of the water of the Danube bear so close a relation one to the other that we cannot treat them separately. We may draw the following general conclusions: In winter the water is usually turbid and green to yellowish-green; the melting snow and ice in the spring with the consequent rise of level, together with the influence of the drainage water, increase the turbidity and make the color of the river even more yellow. That the color of the Danube never is blue except in the song, is well known. At best the water is greenish and usually it is a dirty yellow. On the other hand, after a few windless days in late autumn, winter and occasionally in spring, the water of the ' old Danube ' becomes quite clear and appears a beautiful blue. Apart from the presence of plankton, the transparency and change of color of the water vary with the suspended particles of sand or mud which are removed from the shore or the low islands by strong winds or high waves; are carried in by drainage water from the ground and also from the right bank; or are brought down by the melting snows in the spring."

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[28] Zoologische Jahrbücher, Abth. für Systematik, Geographie und Biologie der Thiere 15, 7 (1902).

The work of Aitken and Spring would seem to have settled the whole question were it not that Lord Rayleigh[29] has recently brought the matter up again. "A recent voyage around Africa recalled my attention to interesting problems connected with the color of the sea. They are not always easy of solution in consequence of the circumstance that there are several possible sources of color whose action would be much in the same direction. We must bear in mind that the absorption, or proper, color of water cannot manifest itself unless the light traverse a sufficient thickness before reaching the eye. In the ocean the depth is of course adequate to develop the color, but if the water is clear there is often nothing to send the light back to the observer. Under these circumstances the proper color cannot be seen. The much admired dark blue of the deep sea has nothing to do with the color of water, but is simply the blue of the sky seen by reflection. When the heavens are overcast the water looks gray and leaden; and even when the clouding is partial, the sea appears gray under the clouds, though elsewhere it may show color. It is remarkable that a fact so easy of observation is unknown to many even of those who have written from a scientific point of view. One circumstance which may raise doubts is that the blue of the deep sea often looks purer and fuller than that of the sky. I think the explanation is that we are apt to make comparison with that part of the sky which lies near the horizon, whereas the best blue comes from near the zenith. In fact, when the water is smooth and the angle of observation such as to reflect the low sky, the apparent blue of the water is much deteriorated. Under these circumstances a rippling due to wind greatly enhances the color by reflecting light from higher up. Seen from the deck of a steamer, those parts of the waves which slope towards the observer show the best color for a like reason.

"The real color of ocean water may often be seen when there are breakers. Light, perhaps directly from the sun, may then traverse the crest of the waves and afterwards reach the observer.

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[29] *Nature,* **83**, 48 (1910); Scientific Papers, **5**, 540 (1912).

In my experience such light shows decidedly green. Again, over the screw of the ship a good deal of air is entangled and carried down, thus providing the necessary reflection from under the surface. Here also the color is green.

"The only places where I have seen the sea look blue in a manner not explicable by reflection of the sky were Aden and Suez. Although the sky was not absolutely overcast, it seemed that part at any rate of the copious, if not very deep, blue was to be attributed to the water. This requires not only that the proper color of the water should here be blue, but also the presence of suspended matter capable of returning the light, unless indeed the sea bottom itself could serve the purpose.

"The famous grotto at Capri gives an unusually good opportunity of seeing the true color of the water. Doubtless a great part of the effect is due to the eye being shielded from external glare and so better capable of appreciating the comparatively feeble light which has traversed considerable thicknesses of water. The question was succesfully discussed many years ago by Melloni, who remarks that the beauty of the color varies a good deal with the weather. The light which can penetrate comes from the sky and not directly from the sun. When the day is clear, the blueness of the sky coöperates with the blueness of the water.

"That light reflected from the surface of a liquid does not exhibit the absorption color is exemplified by brown peaty water such as is often met with in Scotland. The sky seen by reflection is as blue as if the water were pure. But an attempt to illustrate this fact by experiment upon quite a small scale was not at first successful. A large white photographic dish containing dark brown oxidized 'pyro' was exposed upon the lawn during a fine day. Although the reflected light certainly came from the clear sky, the color did not appear pronounced, partly in consequence of the glare of the sunshine from the edges of the dish. The substitution of a dish of glass effected an improvement. But it was when the eye was protected from extraneous light by the hands, or more perfectly by the interposition of a pasteboard tube held close up, that the blue of the reflected light manifested its proper purity. It would seem that the explanation is to be sought in diffusion of light within the lens of the eye in consequence of which, especially in elderly persons, the whole field is liable to be suffused with any strong light finding access.

" As regards the proper color of pure water, an early opinion is that of Davy, who, in his *Salmonia,* pronounces in favor of blue, basing his conclusion upon observations of snow and glacier streams. The latter, indeed, are often turbid, but deposit the ground-up rock which they contain when opportunity offers, as in the Lake of Geneva. A like conclusion was later put forward by Bunsen on the basis of laboratory observations. The most elaborate experiments are those of Spring, who, in a series of papers published during many years, discusses the difficult questions involved. He tried columns of great length—up to 26 metres; but even when the distance traversed was only 4 or 5 metres, he finds the color a fine blue only to be compared with the purest sky-blue as seen from a great elevation. But when the tubes contain ordinary water, even ordinary distilled water, the color is green, or yellow-green, and not blue.

" The conversion of the original blue into green is, of course, explicable if there be the slightest contamination with coloring matter of a yellow character—*i.e.,* strongly absorbent of blue light. Spring shows that this is the effect of minute traces—down to one ten-millionth part—of iron in the ferric state, or of humus. The greenness of many natural waters is thus easily understood. Another question examined by Spring is not without bearing upon our present subject—viz., the presence of suspended matter. I am the better able to appreciate the work of Spring, that many years ago I tried a variety of methods, including distillation *in vacuo,* in order to obtain water in the condition which Tyndall described as 'optically empty,' but I met with no success. Spring has shown that the desired result may be obtained by the formation within the body of the liquid of a gelatinous precipitate of alumina or oxide of iron, by which the fine particles of suspended matter are ultimately carried down.

" Perhaps the most telling observations upon the color of water are those of Count Aufsess, who measured the actual transmission of light belonging to various parts of the spectrum. The principal absorption is in the red and yellow. In the case of the purest water there was practically no absorption above the line F, and a high degree of transparency in this region was attained even by some natural waters. That these waters should show blue, when *in sufficient thickness,* is a necessary consequence.

" In my own experiments, made before I was acquainted with the work of Aufsess, the light traversed two glass tubes of an aggregate length of about 4 metres (12 feet). On occasion the light was reflected back so as to traverse this length twice over. I must confess that I have never seen a blue answering to Spring's description, when the original light was white. For final test I was careful to employ the light of a completely overcast day, which was reflected into the tubes by a small mirror. The color, after transmission, showed itself very sensitive to the character of the original source. The palest clear sky of an English winter's day gave a greatly enhanced blue, while, on the other hand, isolated clouds are usually yellowish, and influence the result in the opposite direction. I should myself describe the best color of the transmitted light on standard days as a greenish blue, but there is some variation in the use of words, and, perhaps, in vision. Some of my friends, but not the majority, spoke of blue simply, but all were agreed that the blueness of a good sky was not approached. The waters tried have been very various. Sea-water from outside the grotto of Capri, from Suez and from near the Seven Stones Lightship off the Cornish coast, I owe to the kindness of friends. Of these the two former showed a greenish-blue, the latter a full, or perhaps rather yellowish, green, and these colors were not appreciably modified after the water had stood in the tubes for weeks. It is important to remember that the hue may to some extent depend upon the thickness. It is quite probable that in a greatly increased thickness the Capri and Suez waters would assume a more decided blue color. But I do not think the Seven Stones water could so behave, the color, with 12 feet, seeming to involve the absorption of blue light. Further observations on greater depths of sea-water would be desirable. A naval son informs me that off the coast of Greece a plate lying in 6 fathoms of water looked decidedly blue, although the sky was a dirty gray. I have doubts whether this would be generally the case in the Mediterranean; the green due to moderate thicknesses seems too decided.

"Of natural fresh waters that I have tried, none were better than that from a spring in my own garden. This water is hard, but bright and clear, and it shows a greenish-blue, barely distinguishable from that of the Capri and Suez water. Distillation does not improve the blue. Neither did other treatments do any good, such, for example, as partial precipitation of the lime with alkali, or passage of ozone with the idea of oxidizing humus. Wishing to try water of high chemical purity, I obtained—through the kind offices of Sir J. Dewar—water twice distilled from alkaline permanganate, and condensed in contact with silver, but the color was no bluer. In the light of this evidence I can hardly avoid the conclusion that the blueness of water in length of 4 metres has been exaggerated, especially by Spring, although I have no reason to doubt that a fully developed blue may be obtained at much greater thicknesses. I should suppose that sufficient care has not been taken to start with white light. It may be recalled that overcast days are not so common in some parts of the world as in England.

"A third possible cause of apparent blueness of the sea must also be mentioned. If a liquid is not absolutely clear, but contains in suspension very minute particles, it will disperse light of a blue character. Although, undoubtedly, this cause must operate to some extent, I have seen no reason to think that it is important. But the existence of three possible causes of blueness complicates the interpretation of the phenomena. Hitherto, observers have not been sufficiently upon their guard to distinguish blueness having its origin in the sky from blueness fairly attributable to the water itself."

The question at issue seems to be whether Lord Rayleigh's negative results are to outweigh Spring's positive results. On general principles, there are so many ways of failing in an experiment that a positive result usually outweighs any number of negative ones. On the other hand, Lord Rayleigh is such a careful worker that his conclusions are not to be rejected hastily. The fact that he does not give details to the same extent that Spring does cannot be charged against him because he was delivering an address before the Royal Institution while Spring was writing a series of scientific papers. The whole question must therefore be considered as open for the present though one may at least hope that Spring will prove to be right.

Beebe[30] seems to feel that the color of water is entirely an optical illusion. "One finds numerous examples of these sensory deceits at sea. The wind flutters the fins of the flying fish and we think they actually fly. The tropic sea, under the palest of green skies, is saturated ultramarine, save where the propellers churn it to pea-green, yet in our bath the water is clear and colorless. . . . The great unlovely bow rose and reached forward and settled, until, as I lay face-downward our speed seemed increased manyfold. And I wondered if the wooden expression which always marked the figure-head ladies and gods had not its origin in the hypnotic joy of forever watching the molten cobalt crash into alabaster, this into emerald, then to merge again into the blue, which is a hue born of depth and space and not of pigment."

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[30] "Sea-Wrack." *Atlantic Monthly*, 1918, 481.

CORNELL UNIVERSITY.

Researches on Fog-Signal Sound Measurement. L. V. KING. (*The Honorary Advisory Council for Scientific and Industrial Research,* Dominion of Canada, Bulletin No. 2, Ottawa, 1918.)—Canada has been among the most progressive of maritime countries in the experimental development of fog-alarm systems. The type of fog-alarm which has found favor in Canadian waters, and has been installed in many localities, is a modified form of compressed-air siren, known as the "diaphone." The original diaphone was invented by Dr. Owen Hope-Jones. Its utilization for fog-alarm purposes was first suggested by Lieut-Col. Anderson, Chief Engineer of Department of Marine and Fisheries of Canada, who with his chief assistant, Mr. B. H. Frazer, determined from numerous tests the lines along which the diaphone evolved into full-sized fog-signal apparatus in the hands of Mr. J. P. Marthey of Toronto.

Although powerful sirens have been in use in all maritime countries for nearly half a century, there was until recently comparatively little accurate information available regarding the way in which sound waves were actually generated in such apparatus. It has long been known that existing types of sirens or steam whistles are extremely inefficient; that is, little of the power furnished is converted into sound of such a character or quality as will penetrate a desired distance in foggy weather. The extent to which it is possible to protect a trade route in this way from accidents due to fog depends ultimately on the power, penetration and reliability of the fog-alarms which can be installed and operated at a given cost. The difficulty in the development of what may be called "acoustic engineering" has been the almost total lack of sound-measuring instruments. The development of fog-signalling machinery has also been retarded by the fact that experimental tests are not only very costly but have had to be conducted at isolated stations far removed from laboratory facilities.

From the work of Lord Rayleigh, Webster and others, it was known that the proportion of power converted into sound with musical instruments was exceedingly small, in many cases less than one part in a thousand. It was found that the sound from a diaphone unprovided with a trumpet was extremely complex, and that the effect of a trumpet of correct design was to concentrate a greater proportion of the power into the master tone. During propagation through the atmosphere, the overtones do not travel far but are filtered out, the master tone surviving to an appreciable extent at distances greater than two miles. It is now possible to state in horse power or watts the total acoustical output of a siren as well as to compute the relative proportion of power expended in the master tone and overtones. That this may be done as a test is of great importance, as the designer will now be able to predetermine the behavior of fog-signal apparatus without having the equipment installed at great expense at some station by the sea. It is to be expected that with the methods of carrying out the required tests available, the development and improvement of sirens will be much more rapid than in the past.

Chemical Warfare—A New Weapon. E. HENDRICK. (*Chemical and Metallurgical Engineering,* vol. xx, No. 4, p. 152, February 15, 1919.)—The opinion seems to prevail generally that the use of poison gas, launched in breach of faith by the German high command, has reached an end for all time; that by general agreement in convention it will no longer be endured, and that it will be classed with the many practices of violence and debauchery of which the Germany army was guilty. This is not in accord with the opinion of Brigadier-General Amos A. Fries of the U. S. Engineers, who was in command of the chemical warfare service of our army in action. The allied troops used chemical warfare in constantly increasing measure because it is an effective weapon. On the other hand atrocities were neither encouraged, practiced or permitted. It is General Fries' belief that the use of other chemicals besides shot and shell, having been introduced into the art of war, can never be eliminated. The situation is somewhat like that when gunpowder was introduced, and universally frowned upon as unfair and unsportsmanlike; yet it has endured.

While conventions may agree to forbid the practice of chemical warfare, it is a remarkable weapon of offense. Its employment places an army at so great an advantage over an unprepared enemy that it will be difficult to trust nations to forego its use. It is exceedingly inviting for police work, because it may be made effective without involving fatal casualties or maiming. The question, therefore, must be met whether future wars shall be controlled or not. If they are to be fought under international supervision, under rules akin to an international code duello—in which event it would seem that swords alone should be the proper weapon—then we have every reason to hope for the best, so long as the supervisors do not get to fighting among themselves. On the other hand, it may be that scientific warfare will be recognized, and allowed to develop until war itself shall be prohibited by some working agreement, owing to its destruction of the world's accumulated property. Half way measures and compromises do not meet the situation. If there is to be an international police, the chemical munitions will be needed to avoid unnecessary loss of life.

INSTITUTES OF APPLIED SCIENCE.*

BY

P. G. NUTTING, Ph.D.,

Engineer in charge of Research Laboratory, Westinghouse Electric and Manufacturing Company

The future of any nation depends in large measure upon the degree to which fundamental principles are developed and applied to the solution of its national economic and industrial problems great and small. And as between our need of knowledge and our need of experts to apply that knowledge, it is difficult to say which is greater. Our supply of either is woefully inadequate and likely to continue so under our present system of research institutions. The remedy for this condition here proposed may possibly prove to be a solution of the problem.

Experts are produced and our store of knowledge is increased by the working out of individual concrete problems, and by no other means. This statement is almost a platitude and is accepted generally by all thinking men. But the national problem of the most efficient means of obtaining the best results has apparently been given little consideration. Research institutions we have, of high quality and in considerable numbers, but none of them are well adapted to fill our national need. By way of illustration, let us first consider the results obtained by each of the seven or eight distinct types of existing research institutions and the extent to which they meet the requirements of the nation.

A research institution to be efficient in turning out experts and vital fundamental principles should possess the following qualifications:

1. The breadth of the field covered should not be too wide nor too narrow—preferably such as may be adequately covered by a staff of not less than twenty nor more than one hundred men. Lists of typical fields of intensive research are given farther on in this article.

2. The director and the leader in each of the five to ten subfields should be the recognized leaders in their fields.

3. Close contact with corresponding industries should be maintained through suitable location and selection of research problems.

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* Communicated by the Author.

4. There should be maintained the closest coöperation and team work between members of the staff, with free and full discussion of plans and results. Given the proper organization and a director generous with ideas and advice and tactful in handling men, this matter presents few difficulties.

5. With the possible exception of a few leaders, members of the staff should be free to enter and leave the institution as they see fit. An annual turnover of from 10 to 30 per cent. of the staff is perhaps the most advantageous.

6. There should be no domination over research by untechnical men, and the least possible by the leading members of the staff.

7. Freedom to publish results, undertake outside work and otherwise profit by his work should be recognized in every member of the staff.

Each of the existing types of research organizations falls short of meeting the requirements just mentioned in at least one item. The seven principal types in this country are as follows:

University Research.—This is excellent for the teaching of fundamental principles in both the principal and in related subjects and also in regard to freedom of choice of work, but it is essentially preparatory in the process of making experts. Aside from some work by a few instructors, there is little continuity to the work, and therefore large problems as a rule are not attempted. There is practically no team work between men working on the same group of problems. There is also little or no direct contact with technical work and practical industrial problems, and therefore very little incentive from without.

Government Research.—The characteristics of research in the best government bureaus are intermediate between those of the university and industrial types. The tendency is to be too academic, due partly to heavy recruiting of the staff directly from universities and partly to defective contact with the more important technical problems. Excellent work in biological research is done in various bureaus, but even these are by no means well adapted to turning out well and broadly trained experts.

Industrial Research, General Type.—In the best-organized industrial research laboratories the field covered is appropriate. Team work and coöperation are highly developed. There is ample incentive to development and just the proper amount of contact with technical work. From the national standpoint, the expansion of these means inefficient duplication of work, and they are never regarded as schools for turning out experts for the benefit of the public. Conditions 1 to 4, described above, are fulfilled very closely, whereas in regard to 5, 6 and 7, they fall wide of the mark.

Industrial Research, Piece-Work Type.—Such laboratories as the Mellon Institute are in close contact with technical problems and men are free to come and go. There is, however, almost no team work and very little coöperation nor continuity of effort. Working on individual isolated jobs is not an efficient means of developing broad groups of fundamental principles, and the experts turned out by this type of laboratory are seldom men of broad training and experience.

Private Consulting Research.—The few private consulting research laboratories of the type of A. D. Little, Inc., are in close contact with important technical problems and team work is well developed. Their defect is in covering too broad a field and in doing too little intensive work of a general character. They are fitted to turn out practical money-making experts, but not to advance any applied science in general.

Coöperative Testing and Research.—There are a few efficient laboratories doing important testing and research which are purely coöperative organizations, such as the Electrical Testing Laboratories of New York. Very little fundamental research is attempted and very few experts of broad training are turned out. However, both this and the preceding type demonstrate that research laboratories may be made self-supporting.

Foundation Research.—Such special research laboratories as have been fostered by the Carnegie Institution are well adapted to developing experts as well as increasing our knowledge of fundamental principles. The Geophysical Laboratory, the Magnetic Laboratory and the Mount Wilson Observatory are ideal in their freedom from financial domination, and are splendidly adapted to take care of neglected fields of research. It is, however, unnecessary and probably undesirable to provide such endowed laboratories throughout the field of industry, while the industries chiefly benefited are so well able to finance them.

In passing, it may be well to cite other proposed methods of research having precisely the objectives outlined in our introduction. Of large national grants of money for wholesale research not much is to be expected, since it is unlikely that conditions 1 to 5, above, will be fulfilled. If, however, such research were subdivided into suitable organizations, each intelligently directed, there would be little to criticize in the scheme. Again, massive bodies of eminent scientists are unlikely to be productive, however ably assisted. Here again, if subdivided into suitable groups, such bodies of scientists might well exercise a beneficent influence on such institutions as are proposed. State controlled institutes of research might be organized to operate efficiently, but more or less obstructive political or academic control would be anticipated.

The Research Institute.—The proposed new form of research institution would take men from the universities, already thoroughly grounded in the known fundamental principles relating to their chosen lines, and provide them with ample facilities (salary included) for actual vital research along those lines, each in company with a score or hundred other men working along more or less closely related lines. Our best industrial research laboratories have demonstrated that this is a very efficient means of developing experts. Our universities are unfitted for indefinitely holding large bodies of investigators, for they either cannot pay them reasonable salaries or else require the major portion of their time for teaching. Further, but few universities are well provided with productive research problems for their advanced students.

While industrial research laboratories may produce great experts in a minimum of time, the future of these experts is tied up with the concern to which they are attached. Any valuable results obtained are, of course, the property of the company. In the proposed form of research institution each individual would be more or less arbiter of his own destiny, free to come and go and dispose of himself or the results of his labors more or less as he sees fit. It is planned to have every member of these institutes quite free to accept calls for consulting work from anyone, anywhere at any time. Since private consulting research laboratories, so inefficiently organized (since covering too broad a field and with the staff not necessarily made up of the highest grade experts), can show a cash balance, it seems more than likely that a carefully organized body of men, greater in number and working more intensively in a narrower field, would pay even better.

What it is planned to establish is a series of Institutes of Applied Science in each of about thirty fields of applied science, each consisting of from twenty to one hundred men, covering intensively a rather narrow field and each engaged on the type of research characteristic of the best industrial research laboratories. It would probably be best to have such institutions incorporated and under the nominal directorship of one of our scientific or engineering societies. Capital would be required to start such an institute, but if incorporated it would be in an excellent position to finance itself eventually when fully staffed with experts. A moderate salary should be paid, with the expectation that it would be supplemented with consulting fees. The less remunerative research would be attractive to some who would hope thereby to obtain a reputation of cash value. For persons of independent means wishing to do research for its own sake, no better opportunity could be offered anywhere than in such an institute.

In order to illustrate the point of proper depth of field a list is given below of fields for research adapted for being covered in individual research institutes. Some of these might well perhaps be subdivided. Others might be initially treated in groups and subdivided later. In most cases the most advantageous location or locations are obvious. For example, an institute devoted to problems in ferrous metallurgy might well be located in Pittsburgh, an institute of ceramics in either New Jersey, Ohio or Illinois, applied optics in Rochester, rubber products in Ohio, etc. In some lines—for example, in agriculture—it would appear advisable to have from five to ten institutes of a kind, even at the risk of considerable duplication in the research work done. The agricultural experiment stations at various state universities under government subsidy are doing excellent work as a rule, but many of these would be improved by being remodeled and expanded.

Institutes of Research in Applied Science.

- Agriculture:
  - Agronomy
  - Animal Husbandry
  - Dairying and Dairy Products
  - Fruit and Fruit Products
  - Soils and Fertilizers
- Applied Optics
- Astronomic Research
- Atmospheric and Solar Research
- Building Materials
- Ceramic Products
- Dyes and Dye Products
- Electrochemical Processes
- Explosives

- Fats, Oils and Waxes
- Fisheries and Fish Products
- Food and Food Products
- Forestry and Forest Products
- Fuel and Fuel Products
- Geodetic Research
- Geophysical Research
- Leathers, Glue and Gelatine
- Medical Research on:
  - Cancer
  - Contagious Diseases
  - General Bacteriology
  - Surgery
  - Tuberculosis
- Metallurgy:
  - Ferrous
  - Non-Ferrous
  - Rare Metals
- Paints, Oils and Varnishes
- Paper and Cellulose Products
- Petroleum and Petroleum Products
- Pharmacy and Physiological Chemistry
- Public Health and Sanitation
- Radio Communication
- Roads and Road Materials
- Rubber and Rubber Products
- Starch and Starch Products

Such institutes would cost on the average perhaps $120,000 for the plant and equipment, and say $60,000 per year for operating expenses. The director and say six section heads should receive a direct salary of from four to six thousand. Twenty or thirty of the more experienced men should receive salaries ranging from one to four thousand. Fellowships paying say six hundred should be offered all worthy applicants to the limit of accommodations. Ten to sixty per cent. of consulting fees might well be turned over to the institute. Likewise, firms sending their own men to the institute for special research should contribute a percentage for the privilege. In time almost any well-managed research institute should become self-supporting. The initiative might well be taken by a group of consulting specialists, groups of related industries or by the national government itself. The chief dangers to be avoided are in attempting to cover a field too broad to permit of intensive research and in non-scientific domination. They should in every case be under the nominal control of one of our scientific or technical societies.

For the sake of comparison, lists are given below of schools for special instruction in which the primary object is to develop experts rather than to advance knowledge. These fall naturally into two classes, the engineering and the civic types. Such schools of special instruction may well be and in fact are, fairly well taken care of by our better universities and technological institutes. Instruction is chiefly through testing and research, but of such a nature that it does not involve much team work nor application over a period of years. Along these lines the future expert may step directly from the university into field work.

INSTITUTES OF EXPERT INSTRUCTION.

Engineering Type.

- Aeronautic Engineering
- Automotive Engineering
- Building Construction
- Electrical Construction and Operation
- Forestry
- Heating and Ventilating Engineering
- Illuminating Engineering
- Inland Waterway Engineering
- Irrigation Engineering
- Medicine, Dentistry, Surgery
- Meteorological Engineering
- Military Science
- Mining Engineering
- National Defense
- Naval Construction
- Navigation
- Railway Engineering
- Road Construction
- Sanitary Engineering
- Surveying and Geodesy
- Telephone and Telegraph Construction and Operation
- Water Power Engineering

Civic Type.

- Appraising and Accounting
- Banking and Finance
- Charities and Corrections
- Civic Administration
- Commerce and Trade
- Communication
- Education
- Efficiency and Cost Engineering
- Employment
- Fisheries and Game
- Insurance
- Journalism and Information
- Law: Corporation
    - Criminal
    - International
    - Patent
- Marketing and Buying
- Penology
- Recreation and Physical Training
- Statistics
- Taxes and Tariffs
- Transportation

The time is ripe for professional research on a large scale. We have been experimenting with research methods long enough. The wide gap between the university and the real expert must be closed. Let dilettantism in research by amateurs be displaced by the concentrated efforts of strong men working in coördination toward definite ends. Our national welfare demands it and we are well prepared. We are committed to the sensible plan of developing expert knowledge and applying it to all our practical problems. Let us also apply this principle to research itself.

PITTSBURGH, PA.,
January, 1919.

The Next Step in Applied Science. G. T. W. PATRICK. (*The Scientific Monthly,* vol. viii, No. 2, p. 118, February, 1919.)—It was long ago that Plato taught that science should not be applied to the mechanical and industrial arts, but to education, social culture and social health. A century and a half have passed since Rousseau's celebrated essay, in which he tried to show that the arts and sciences had done nothing to advance human happiness. From our modern viewpoint, these were the pathetic mistakes of great men, so richly, as we think, has science vindicated itself in its practical application. While we may not question the almost unlimited possibilities in the application of science to social welfare, nevertheless we may raise the question whether science has thus far been applied to the right things. We may not, indeed, question the potential value of applied science, nor even its actual value in countless directions. What we may question is whether there has been a mistaken conception to the general end to which science should be applied in respect to real social welfare.

Applied science has surrounded us with comforts, conveniences and luxuries of every kind; but just what will be the effect upon a race of men, disciplined through a hundred thousand years of hardships, of this sudden introduction to comfort? Possibly science should never have been applied to making man comfortable, but to making him perfect. It may be that there is great danger in comfort. The biologist holds it in grave suspicion; degeneracy is its sequel. Another of the most brilliant triumphs of applied science is seen in our countless and wonderful labor-saving devices. We simply assume that increased wealth and decreased labor are human blessings, although both may be quite the opposite. It has been seriously questioned whether civilized man has gained enough moral and physical poise to be trusted with the immense wealth which applied science, working upon our suddenly acquired store of coal and iron, has supplied. Then there are the time-saving devices. It is, no doubt, because of the temper of the day that so few have questioned their intrinsic value. But with all these time-saving devices, it is not quite apparent that we have any more time than formerly. Even if there results a certain amount of leisure, much depends upon the manner in which the leisure is spent.

Science has always been applied, and successfully, to our immediate needs as they were understood. The immediate needs of our present time are not more wealth and more luxury and more efficiency, but more social and constitutional power of resistance to physical disease, and more individual power of resistance to every alluring immediate joy which threatens the permanent welfare of society. We need steadiness and self-control and the limitation of our desires. The centrifugal motive which has ruled the world for the last fifty years has gone far enough. The world is small and there are limits to the expansive opportunities both of the nation and the individual.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

ELECTRICAL CHARACTERISTICS AND TESTING OF DRY CELLS.[1]

By G. W. Vinal and H. D. Holler.

[ABSTRACT.]

THIS circular summarizes the available information on dry cells. A brief description of the materials and methods of construction, and elementary theory of the operation of the cells is given. The various sizes and kinds of dry cells on the American market are described. The electrical characteristics of the cells and methods of testing them are discussed. In an appendix are given the proposed specifications for dry cells which have been prepared by the Bureau.

OPTICAL CONDITIONS ACCOMPANYING THE STRIÆ WHICH APPEAR AS IMPERFECTIONS IN OPTICAL GLASS.[2]

By Lt. Commander A. A. Michelson.

[ABSTRACT.]

STRIÆ are conveniently divided into two classes; 1st, those which appear as isolated bright streaks; 2nd, those in which such streaks are numerous, forming bright irregularly continuous bands. Optical investigation with two forms of interferometers shows that the former are due to laminæ of smaller index and of thickness of the order of a hundredth of a mm. They do not seriously affect the optical qualities of lenses or prisms. The second class of striæ in general does not affect the optical performance; but, in the case of lenses and plane parallel plates, etc., in which the light traverses the striæ at approximately normal incidence, the performance may be quite as good as with a perfect specimen.

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* Communicated by the Director.

[1] Circular 79.

[2] Scientific Paper No. 333.

CONSERVATION OF TIN IN BEARING METALS, BRONZES, AND SOLDERS.[3]

By G. K. Burgess and R. W. Woodward.

[ABSTRACT.]

This paper gives practical suggestions for the conservation of tin in bearing metals, bronzes, and solders; much of the data having been obtained from questionaires sent to representative manufacturers and users of the above named alloys. Tables are given showing the chemical composition and physical properties of many of the suggested alloys and also for service tests of genuine babbitt and a high lead bearing metal. Tentative recommendations for standard grades of bearing metal are also included.

Proper solders for various industrial uses are recommended and a new solder consisting of a preponderance of lead with small amounts of tin and cadmium is desired.

Selenium for Red Glass. Anon. (*American Chemical Society News Service Bulletin No. 223,* February, 1919.)—Engine drivers and motormen who fail to distinguish the hues of colored lights may not always be growing color-blind. According to Mr. H. E. Howe, of the American Chemical Society, tests show that not only the eyes must be perfect in their color perception, but that the utmost care must be taken by the chemist in choosing the material for coloring glass.

Red as a danger signal and green for a clear track are firmly established in railroading. A veteran engine driver who was suspected of failing vision properly identified a red light at close view, but at a considerable distance pronounced it green. The man's color perception was growing weak, particularly so far as red was concerned. The red glass of the lantern permitted some green rays to pass and while all eyes would not have perceived them, others with peculiar characteristics would have done so. The red discs employed were made of copper ruby glass. Glass that is unquestionably red owes its true transmission of red rays to the presence of a waste material, a by-product of copper refining for which chemistry had been seeking a use—selenium. If selenium ruby glass be compared with other ruby glass by means of the spectroscope, those colors toward the blue end of the spectrum fail to pass, while various wavelengths are transmitted through other less reliable vitreous material.

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[3] Technological Paper No. 109.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

EXAMINATION OF ORGANIC DEVELOPING AGENTS.[1]

By H. T. Clarke.

[ABSTRACT.]

THE commoner developing agents are classified into four main groups, based upon their solubility in water, ether, and alcohol. Group I, insoluble in water, comprises p-Hydroxyphenylglycine; Group II, soluble in ether, includes Hydroquinone, Chlorhydroquinone, Catechol, and Pyrogallol; Group III, soluble in alcohol, consists of p-Aminophenol and its hydrochloride, 5-Amino-2 hydroxytoluene hydrochloride, 2-4 Diaminophenol hydrochloride, p-Dimethylaminophenol oxalate; Group IIIa, insoluble in alcohol, consists of p-Aminophenol sulphate, 5-Amino-2-hydroxytoluene sulphate, p-Methylaminophenol sulphate, p-Dimethylaminophenol sulphate, o-Methylaminophenol sulphate, and p-Phenylenediamine hydrochloride.

The different members of these groups are partly distinguishable by their behavior on treatment with sodium carbonate, ferric chloride, and silver nitrate solutions.

The salient properties of each substance are described, and the melting points of characteristic derivatives, such as those produced by acetylation and benzoylation, are recorded.

A few methods for the quantitative examination of developing agents are indicated, and several typical analyses of genuine and spurious products are quoted.

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* Communicated by the Director.

[1] Communication No. 73 from the Research Laboratory of the Eastman Kodak Company, published in *Jour. Ind. & Eng. Chem.*, vol. 10, p. 891, November, 1918.

Solders for Aluminum. ANON. (*Circular of the Bureau of Standards*, No. 78, January 28, 1919.)—The question is frequently raised in connection with the use of aluminum and its alloys whether they can be satisfactorily soldered, and if so, by what method and with what metals or alloys. Aluminum, and to a greater extent its alloys, can be welded quite satisfactorily by the oxygen-gas process, but often it is not desirable to heat the parts to be joined to the relatively high temperature necessary to weld them in this manner, owing to the resultant distortion of the parts, and a means of joining at lower temperatures is sought. In response to the general interest in the utilization of this method, evidenced by the inquiries which are received, the Bureau has gathered data on the subject, based upon current experience, and made special tests which are here summarized:

All metals or combinations of metals used for aluminum soldering are electrolytically electronegative to aluminum. A soldered joint is therefore rapidly attacked when exposed to moisture and disintegrated. There is no solder for aluminum of which this is not true. Joints should accordingly never be made by soldering unless they are to be protected against corrosion by a paint or varnish, or unless they are quite heavy, such as repairs in castings, when corrosion and disintegration of the joint near the exposed surface would be of little consequence.

The surfaces to be soldered are carefully cleaned with a file or with emery, and are then "tinned" or coated with a layer of the solder by heating the surface and rubbing the solder into it. Solders are best applied without a flux. The composition of the solder may be varied within wide limits. It should consist of a tin base with addition of zinc or both zinc and aluminum, the chief function of which is to produce a semifluid mixture within the range of soldering temperatures. Tin-zinc solders may range from 15 to 50 per cent. of zinc, with the remainder tin. Tin-zinc-aluminum solders may have a varying composition of zinc, 8 to 15 per cent.; aluminum, 5 to 12 per cent.; and the remainder tin.

The higher the temperature at which the "tinning" is done, the better the adhesion of the tinned layer. By using the higher values of the recommended zinc and aluminum percentages given, the solder will be too stiff at lower temperature to solder readily, and the workman will be obliged to use a higher temperature which secures a better joint. A perfect union between solder and aluminum is very difficult to obtain. The joint between previously tinned surfaces may be made by ordinary methods and with ordinary soft solder. Only the tinning mixture need be special for aluminum. There is no reason why a good solder for aluminum need be brittle, as several commercial varieties are, and it is very undesirable that it should be. The tensile strength of a good aluminum solder is about 7000 pounds per square inch. The strength of a joint depends upon the type and upon the workmanship. Much dependence should not be placed upon the strength of a joint.

NOTES FROM THE PHYSICAL LABORATORY OF THE UNITED GAS IMPROVEMENT COMPANY.*

A PRECISION PRESSURE GAUGE.

By Edward J. Brady.

THIS note is a brief description of a precision pressure gauge of high sensibility and great accuracy recently constructed at this Laboratory.

In principle it is virtually a large diameter U tube (6 cm. diam.) filled with some transparent nonvolatile, nonoxidizing liquid such as kerosene or paraffin oil. In each leg is placed a hollow brass float. The two floats are connected together with a fine silk thread which passes downward around a light graduated wheel with jewel bearings immersed in oil at the bottom. The position of the wheel, which is provided with a vernier, is read through a glass window in one end of the box that forms the bottom of the gauge.

Laboratory workers having to do with the accurate measurement of small gas pressure, either plus or minus, are greatly in need of an instrument similiar to the one to be described.

The way in which the differential pressure enters in the formulæ for both the Venturi meter and the Pitot tube may be represented by $P = (f)\ Q^2$ where P is the pressure that must be read and Q is the quantity of material passed. It will be seen that both of the methods become increasingly inaccurate at low velocity, because of the difficulty of measuring small pressures accurately. This gauge ought to increase the usefulness of both the Venturi and the Pitot tube.

A modification of the gauge with an opening to receive the horizontal velocity pressure of the wind might be used as an anemometer.

The two glass cylinders are cemented into the removable cover of a brass box, one end of which has a glass window. To the lower side of the cover is fastened the little yoke supporting the two jewel bearings in which the index wheel or drum revolves. To one arm of this yoke is fastened a projecting piece carrying a vernier flush with the graduated surface of the wheel. There is a small groove on the face of the wheel around which passes the silk thread that holds the two hollow floats almost totally immersed in the fluid. Any pressure P on this liquid in one tube produces a linear motion at the circumference of the wheel of $\frac{p}{2}$.

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* Communicated by the Manager.

The diameter of the wheel was so chosen that a pressure of one inch of distilled water exerted on a parrafin oil, such as kerosene, produces a motion of the periphery of the wheel of 10 divisions. By the aid of the vernier this precision can be increased.

These cylinders are made of glass so that the gauge can be read approximately and from a distance like an ordinary U gauge with the inch mark on the scale between the two cylinders.

Its use as a zero reading instrument capable of indicating pressure differences of less than 10^{-3} inches of water, will now be described.

Upon the little shaft that carries the graduated wheel there is fastened a small mirror, arranged to face toward the glass window in the lower position. About 4 feet in front of the gauge there is mounted a telescope and scale. This can only be used for comparatively small variations in pressure, say less than 2/10″. However, the telescope and scale may be used to measure small differences at pressures of, say, 2″–3″ and 4″, by moving the mirror around on the shaft, so that it has the proper aspect when the gauge is subjected to the above pressures.

This is facilitated by a small bent movable wire, projecting through a stuffing box in the side. It is pushed in sufficiently to interfere with the rotation of the mirror until the float assumes the position corresponding with the pressure whose small variation is to be measured. It is then withdrawn, when the telescope and scale can be used as before.

The glass window may be made a section of a cylinder, so that all rays from the scale would pass normally through the glass, eliminating refraction effects, but this was not found necessary in practice.

The instrument as constructed has twin hollow brass floats and a brass wheel below. The bearings are jewelled, with very little friction. The friction may easily be made as near zero as is possible by making the wheel of aluminum and so proportioning it that the weight of the wheel *in the oil used* is just equal to the buoyancy of the two floats.

Even with the brass wheel having some weight on the bearings, the system has a very definite zero. The motion of the mirror for small displacements is almost critically damped.

The instrument may be dismantled by inserting two small wire hooks through the hose connections at the top to support the floats while the oil flows out at the bottom.

A gauge constructed as above described has been in use at this laboratory and has given entire satisfaction. When not in use a small piece of rubber tubing is connected from one inlet to the other to keep the dust out. With an ordinary U gauge an accumulation of dirt invariably appears at the point where the menisci are read; with this gauge, however, the graduations on both the wheel and the vernier are immersed in the oil and always appear bright and clean.

A SPECIFIC GRAVITY APPARATUS FOR GASES.

By E. J. Brady.

The simplest method of determining the specific gravity of gas would be by means of a U tube with liquid in the lower end, similar to the method used for determining the density of liquids. This method has not been used for gases, because of the extremely small differential pressure that would have to be measured to obtain accuracy. The pressure gauge in the preceding note makes the use of this method possible.

The apparatus devised consisted of a tall tube, through which the gas was passed, having its lower end connected with the precision gauge by means of a four-way cock. At the upper end there is a pilot flame, if the gases being measured are inflammable. The gases being measured passed through this vertical tube, which is opened to the air through a suitable burner at the top. A quarter turn of the cock cuts off the gas and connects this column of gas with the precision pressure gauge, which will immediately indicate a slight suction produced on the gauge, provided that the gas is lighter than the air. This cock may be turned a number of times to obtain check readings on the same sample of gas. Using the telescope and scale as described, we may graduate the scale to read in specific gravity direct. The gravity as shown by a tube of this kind would, of course, include any foreign matter, such as particles of dust or vapors. But, inasmuch as these materials assist in producing the differential pressure in the Pitot tube or the Venturi meter, they should be taken into consideration in applying the formula for these instruments.

Gases heavier than air, such as oxygen, carbon dioxide, etc., may also be measured, the deflection produced being in the opposite direction.

For more accurate work, where the absolute density of the gas is wanted, we might provide a vertical tube for air also. This air could be dried to eliminate the effect of moisture and the whole system surrounded by the constant temperature bath.

Where the density of hot gases relative to air are required, the vertical air pipe could be carried *within* the vertical gas pipe, so that the air would quickly assume the same temperature as the gas being measured. In many places a vertical tube of much greater height would be permissible. In this case the telescope and scale could be dispensed with and the differential pressure read from the Vernier direct.

Remarkable Pitting of Electro-plating. O. P. WATTS. (*Proceedings of the American Electrochemical Society,* April 3-5, 1919.) —When making some lead platings, heavy pitting suddenly and irregularly appeared. After considerable study of the cause, it was finally found to be due to air dissolving in the electrolyte while it was resting over night and cooling, which was then expelled as minute air bubbles on the work when the bath was heated up by the passage of the current. The microscopic bubbles clinging to the work, which had been left immersed in the bath, started the pitting. (J. W. R.) The difficulty was overcome by heating the solution to a little above its working temperature by means of a lead steam coil before resuming plating, whenever the tanks had been out of use for any considerable time.

Similar trouble by gas-pitting may be expected whenever a plating solution that is used for heavy deposits, and operates at an elevated temperature, stands idle and cold for many hours; but if there is a steady evolution of hydrogen from the cathode during normal operation of the bath, as with the cyanide copper or the brass solution, no trouble need be anticipated, for the stream of gas, ascending along the surface of the metal, will prevent bubbles from clinging long enough to form pits in the plating. Pitting may be expected only when the rate of evolution of gas from the work is extremely slow.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

MUTAROTATION OF GELATIN AND ITS SIGNIFICANCE IN GELATION.[1]

By C. R. Smith.

[ABSTRACT.]

GELATIN at and above 35° C. has a constant specific rotation of −123°. Between 35° and 15° C. higher values are obtained which vary with concentration. Below 15° C. the specific rotation reaches a maximum and constant value of −268°. The increase in levorotation is progressive with time, and requires about 16 hours for completion.

These results point to the existence of two forms—Sol Form A, stable above 35° C., and Gel Form B, stable below 15° C.—and a condition of equilibrium at intermediate temperatures represented by the formula

$$\text{Sol Form A} \rightleftarrows \text{Gel Form B.}$$

Gelatin in the highest concentrations (50 grams per 100 cc.) does not form a gel at 35° C. as it exists entirely in the sol form. At and below 15° C. a minimum quantity, 0.6 grams per 100 cc., is necessary to form the "standard gel" which was marked by the resistance of the movements of an air bubble in the polariscope tube. This concentration of gelatin suffers a total change of 0.80°, in rotation between 35° and 15° when the standard gel is produced. In higher concentrations this same change of 0.80°, corresponding to the production of 0.60 gram of Form B, results in the production of the standard gel. The maximum temperatures at which any concentration can produce a gel is conditioned, therefore, by the existence of this amount in equilibrium. The "melting temperatures" become identical with maximum gelation temperatures when sufficient time is given for equilibrium to be reached.

When gelatin is cooled rapidly from 35° to 20°, 19° or 15° in polariscopic tubes and the changing rotation followed with time,

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* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Amer. Chem. Soc.*, v. 41, 1919, p. 135.

it is found that the reaction is bimolecular, showing that the laws of mass action apply to a colloid like gelatin even when in the gel form in which most of the readings were made.

Following up the relation indicated, it was found that two molecules of Sol Form A were in equilibrium with one molecule of Gel, Form B, according to the formula

$$k\ (a-x)^2 = k^1\ x$$

Considering the change from the Sol Form A to the Gel Form B as bimolecular and further that a definite amount of the latter forms the standard gel, a formula was derived which permits the calculation of the time necessary for the production of gel in different concentrations at temperatures below 20° C. $(y^2d - yb)$ $t =$ a constant, where y is the concentration in grams per 100 cc., d the total change in specific rotation observed between 35° and selected temperature, and b the change necessary to produce the standard gel. Experiment gave satisfactory results in agreement with the formula.

INFLAMMABILITY OF CARBONACEOUS DUSTS IN AIR AND IN ATMOSPHERES OF LOW OXYGEN CONTENT.[2]

By H. H. Brown.

Severe property losses, in some cases attended by the destruction of human life, have occurred because of the fact that dusts from all materials which will burn are explosive. The Grain Dust Explosion Investigation Laboratory of the Bureau of Chemistry has investigated the explosibility of such dusts, with a view to ascertaining ways to reduce to a minimum the danger from dust explosions and fires in mills, grain elevators and cotton gins.

The relative inflammability of various dusts was determined in the laboratory, using a modification of the method devised by the Bureau of Mines for testing coal dust. Briefly, this method consists in forcing a cloud of dust (75 milligrams), which will pass through a 200-mesh screen, against a platinum-covered heating element, placed in the centre of a round glass globe with a capacity of approximately 1400 cubic centimeters. The pressure produced by the ignition of the dust was measured by a steam pressure gauge.

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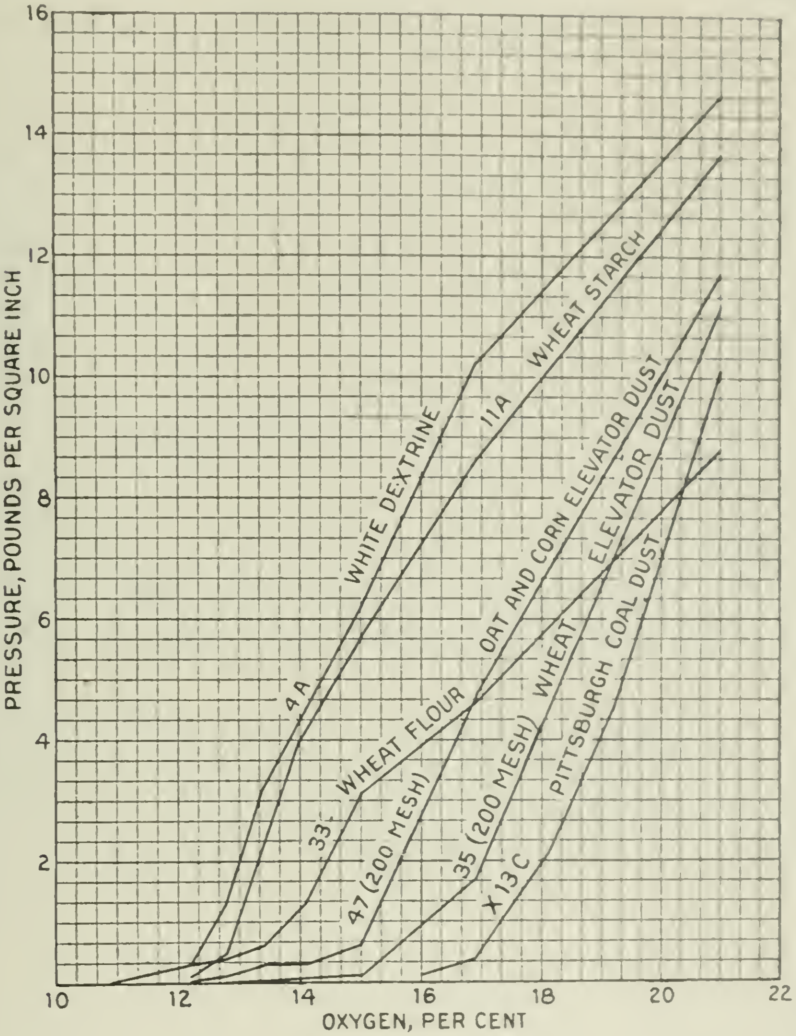
[2] Brown, H. H.: "Inflammability of Carbonaceous Dusts," *J. Ind. Eng. Chem.*, 9 (1917), 269. Brown, H. H., and Clement, J. K.: "Inflammability of Carbonaceous Dusts in Atmospheres of Low Oxygen Content," *J. Ind. Eng. Chem.*, 9 (1917), 347.

The results obtained from a number of tests conducted in this way indicate that the pressure (expressed as pounds per square inch) generated by the ignition of several different types of dust



varies from 17.5 in the case of lycopodium and 15.2 for yellow corn dust from the first break in dry milling, through 13.2 for wheat starch, 11.3 for rice starch and 10.1 for Pittsburgh standard coal dust, to 3.2 for potato starch and 1.1 for gelatin dust from an elevator. Obviously, the dusts tested are highly inflammable, so that a cloud of any one of them suspended in the air forms a dangerous condition.

In the laboratory tests on the inflammability of coal dust, oxygen was employed to blow the cloud of dust against the heating coil, thus creating an atmosphere containing a greater amount of oxygen than is present in ordinary air. The pressures thus obtained exceed those secured when air alone is used. Conversely, lower pressures are shown when the surrounding air is deficient in oxygen.

A series of experiments was conducted to determine the possibility of employing an inert gas, or one lacking in oxygen, as a means for the prevention of dust explosions in industrial plants. The apparatus used was similar to that already described, with the addition of a device which permitted the filling of the explosion chamber with gas of any desired composition. In this way five typical dusts were tested, using gas mixtures ranging in composition from 16.9 per cent. oxygen, 4 per cent. carbon dioxid, and 79.1 per cent. nitrogen to 10.9 per cent. oxygen, 9.2 per cent. carbon dioxid, and 79.9 per cent. nitrogen. The results of this test are clearly shown in the accompanying diagram.

It is evident that an explosion of any of these dusts, which may be regarded as typical carbonaceous dusts of the more inflammable varieties, cannot occur in an atmosphere containing 12 per cent. or less of oxygen, the rest being inert gases. If elevator dusts alone are considered, this limit is extended to 14 or 14½ per cent.

Tests conducted on a larger scale, using standard size milling machinery, have shown that it is possible to prevent explosions in these units by means of an atmosphere of inert gas. Results of such tests are now being prepared for publication.

NOTES FROM THE RESEARCH LABORATORY WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.*

AUTOGRAPHIC MEASUREMENTS OF THE QUENCHING POWER OF LIQUIDS.

By Norman B. Pilling.

[ABSTRACT.]

THE method which has been followed in this work involved the measurement of the rate of cooling of a small metallic cylinder quenched from a certain fixed temperature in the desired quenching medium, the latter being maintained at various temperatures. The temperature within the cylinder was measured with a small insulated platinum thermocouple, the hot junction of which was in good thermal contact with the bottom of an axial hole in the cylinder; the initial temperature of quenching was measured with a potentiometer, and subsequent temperature changes taking place during quenching were measured with a calibrated Enithoven galvanometer and recorded photographically upon a rotating film. Time intervals were also impressed upon the photographic record through suitable connections with a seconds pendulum.

It was not found feasible to use a steel cylinder for a heat reservoir, as the quantity of heat liberated at the transformation temperature was both variable and great enough to mask the temperature changes due to heat abstraction by the quenching liquid alone. An alloy composed of nickel with 5 per cent. silicon met the requirements suitably and had the additional advantage of being extremely resistant to oxidation, thus permitting the same standard to be used repeatedly, avoiding uncertain conditions due to small variations in mass and position of the thermo-element. The standard cylinder was 50 mm. long, 6 mm. diameter and weighed 11.6 grams.

A number of oils and aqueous solutions have been examined through a considerable range of temperature, and the results indicate the comparative stability of quenching power maintained by oils at elevated temperatures as compared with the profound effect which temperature has with aqueous solutions in general upon their ability to absorb heat rapidly, due to changes in the mechanism of heat absorption. As an example, the ratio of the quenching power of water at the freezing point to that at the boiling point, taking the quenching power as proportional to the cooling velocity of the standard cylinder at 700° C., is 1 :20.

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* Communicated by the Engineer in charge.

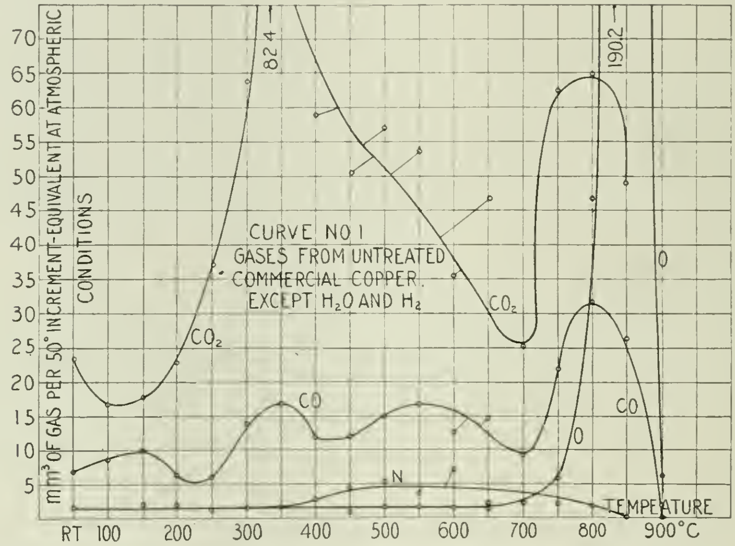
A more extended report on this subject will be published shortly elsewhere.

GASES FROM COPPER.

By H. M. Ryder.

[ABSTRACT.]

IN the course of some work concerning certain of the physical properties of copper, it was necessary to determine gases which could be removed from copper upon heating in vacuum. The copper here used was annealed rolled strap containing .05 per cent. Cu_2 and .025 cm. x .244 cm. x 214 cm. long. This weighed 5 grams approximately and its volume was 1.31 c.c. This was placed in an apparatus developed for this work,[1] and was heated by the passage of an electric current, its temperature being determined by resistance changes. The gas removed was collected, out of contact with the copper, for 12 hour periods, the temperature of



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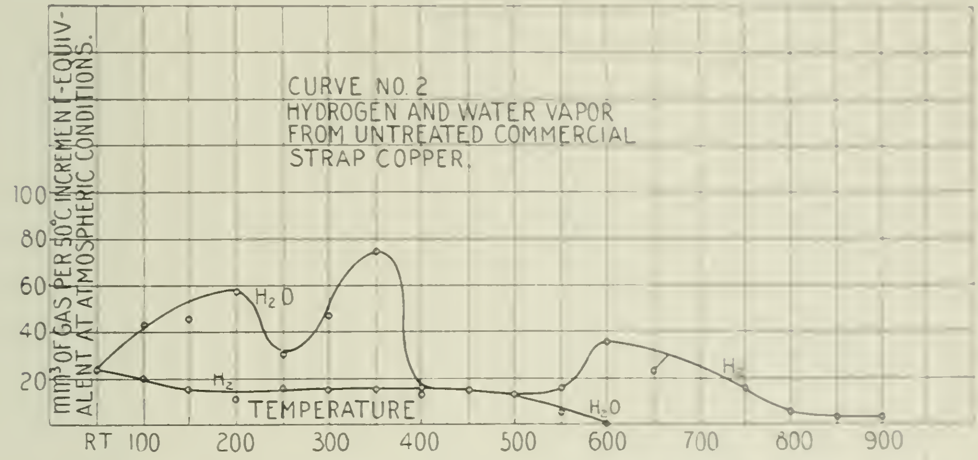
[1] *J. Am. Chem. Soc.*, xl, 1656, Nov., 1918.

the specimen being increased 50° C. immediately after the removal of each sample.

The accompanying curves, plotted for each gas between quantity increment (per 50° rise) and the temperature, show the effect of temperature on the rate of evolution of the various gases. The maximum in the CO_2 curve at 350° C. is probably a property of the gas, since this is present in curves obtained similarly for a number of steels, irons, glasses and for porcelain. It might be possible to vary the shape of this curve by varying the time interval, but the time periods would have to be increased enormously to produce an appreciable change, since most of the gas shown for each point came off during the first half hour after bringing the temperature to the value shown.



The release of the large quantity of oxygen at 800° C. is due to the decomposition of Cu_2O. Sufficient evidence to establish this point will be presented later.

The maximum in the hydrogen curve at 600° C. is due to the fact that copper becomes permeable to hydrogen at this temperature.

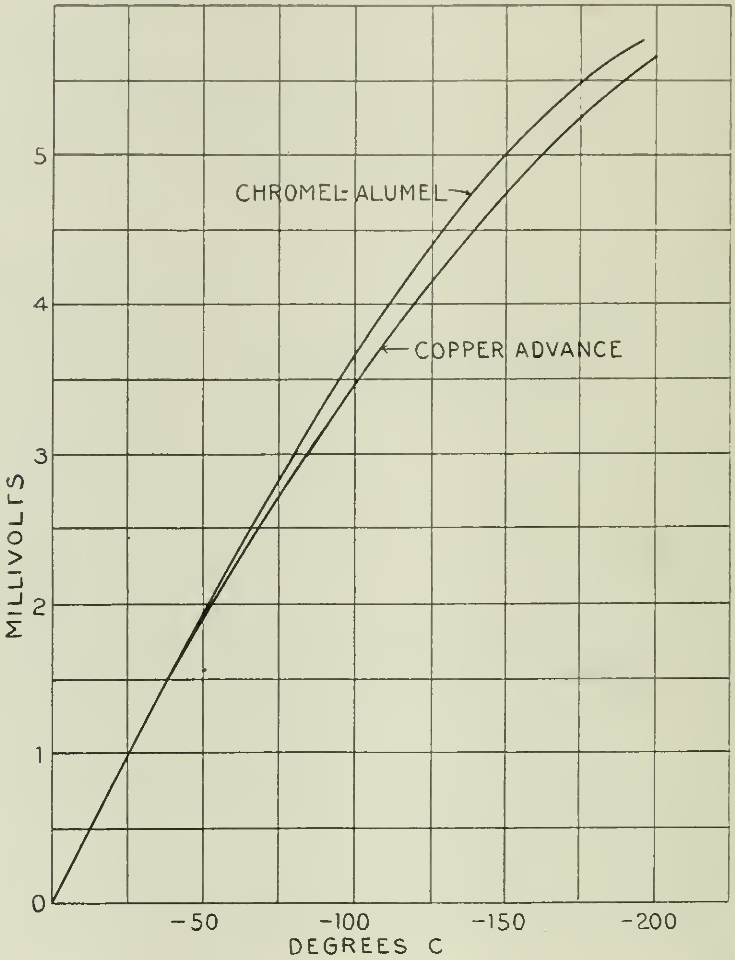
THE MEASUREMENT OF LOW TEMPERATURES WITH THERMOCOUPLES.

By Thomas Spooner.

[ABSTRACT.]

IN connection with some recent investigations, it was necessary to measure temperatures below 0° C. For this purpose thermocouples were the most convenient to use. It was known that copper advance couples were satisfactory for temperatures down to liquid air values, but it was thought that Hoskin's thermocouple alloys, which go under the trade name of chromel-alumel, might be more satisfactory, as they give nearly a straight line calibration at temperatures above 0° C.

FIG. 1.



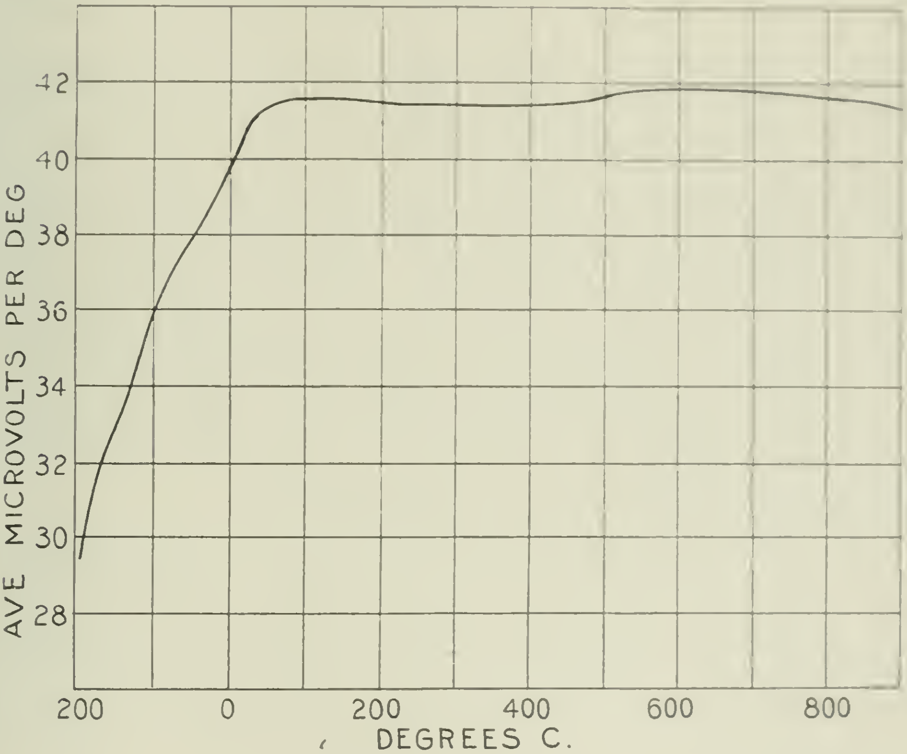
Thermocouple calibrations.

In order to investigate the thermal e.m.f. of the chromel-alumel material at low temperatures, a copper advance couple with its cold junction in ice water was first checked at the freezing point of mercury, at the sublimation point of CO_2 snow and at the temperature of boiling oxygen. These tests gave the following formula for the copper advance couple:

$$e = .03959t + .00004582t^2 - .0000000556t^3.$$

The copper advance couple and the chromel-alumel couple were inserted in holes in an iron cylinder which was then placed in a thermos bottle. Liquid air was poured into the bottle until the iron block reached the temperature of the liquid air. The block was then allowed to warm slowly in the thermos bottle and readings were taken of the e.m.f.'s of the two couples. Fig 1 gives the calibration of the two couples and Fig. 2 the average microvolts per degree between 0° C. and the given temperature

Fig. 2.



Chromel-alumel thermocouple.

from +900° C. to −190°. The high temperature values were obtained by calibration against a standardized platinum-platinum rhodium couple.

It will be noted from Fig. 2 that the microvolts drop off very rapidly below 0° C. and that the chromel-alumel couples show no appreciable advantages over the copper advance at low temperatures.

Big Ordnance Project Abandoned. ANON. (*Arms and the Man,* vol. lxv, No. 26, p. 504, March 22, 1919.)—The Neville Island ordnance project is to be entirely abandoned within the next few months. The buildings which have been erected there will eventually be torn down and the island restored to its original owners. The Neville Island project as originally planned by the Ordnance Department was one of the largest single undertakings of the war. Its estimated cost was $150,000,000, and in size and capacity it was to be larger than either the Krupp Works at Essen or the Creusot Works in France. It was planned with a capacity sufficient to produce fifteen 14-inch, 50-calibre rifles per month, and forty thousand 14-inch and 16-inch projectiles per month. One hundred and sixty-five of these immense rifles were to be turned out in time to be transported to France and on the firing line before May 1 of next year.

Electro-plating on Iron from Copper Sulphate Solution. O. P. WATTS. (*Proceedings of the American Electrochemical Society,* April 3-5, 1919.)—For electro-plating on iron or steel from a copper sulphate solution, platers have in the past found it necessary either to give the metal a preliminary coat of nickel or to plate it with copper from a cyanide solution before transferring the object to the copper sulphate plating bath. Since the sulphate solution is much more satisfactory than the cyanide for the production of heavy deposits of copper, where these are required the plater has been compelled to maintain two different plating solutions, and to perform two distinct plating operations. The desirability of being able to plate directly on steel in the copper sulphate solution is apparent, and many persons have tried to discover a method of doing so, but until recently without success.

It has been discovered recently that by immersing iron for a few moments in an acidified solution of arsenious oxide, an adherent copper-plate may be deposited from an acid electrolyte, but no adequate explanation had been offered for this unique effect of arsenic. In this paper it has been shown that certain solutions of lead and antimony may be substituted for the arsenic dip, previous to direct-current plating of copper on iron from copper sulphate.

It appears to be impossible to obtain a perfect plate on iron from solutions of bismuth chloride by the usual methods of electro-plating; but use of the arsenic or antimony dip is attended with the same successes as in copper plating.

The successful substitution of solutions of antimony and lead for arsenic, and the application of these dips to plating on iron with bismuth, show that the beneficial effect of the arsenic dip is not due to a property peculiar to arsenic alone, but is the result of coating the iron with a metal whose potential in acid solutions is so near to that of copper that it is possible to deposit a good copper plate upon it, yet whose potential is not so far below iron that it will deposit on iron in a powdery, non-adherent form.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, March 19, 1919.)

Hall of The Franklin Institute,
Philadelphia, March 19, 1919.

President Dr. Walton Clark *in the Chair.*

Additions to membership since last report, 3.

Reports of progress were presented by the Committee on Library and the Committee on Science and the Arts.

Mr. Eric A. Lof, Electrical Engineer, General Electric Company, Schenectady, New York, presented a paper on "Hydro-electric Developments." The speaker described the recent advances made in hydro-electric installations, and gave detailed accounts of the operations of the power plants recently erected in the United States and Canada. The water-wheel driven generators, as well as the electrical apparatus which is necessary to complete the equipment of hydro-electric stations were fully described. The subject was illustrated by lantern slides.

After a brief discussion in which the Chairman, Mr. Crisfield, and others participated, the thanks of the meeting were extended to the speaker.

Adjourned.

George A. Hoadley,
Secretary Pro Tem.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, March 5, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 5, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following reports were presented for first reading:

No. 2729: Simplex Fluid Meter.

No. 2730: Monroe Calculating Machine. Advisory.

On the recommendation of the Sub-Committee on Literature, the following awards were made for papers in the JOURNAL, 1918:

No. 2736: The Edward Longstreth Medal of Merit to Dr. Joshua J. Skinner, of the Laboratory of Soil Fertility of the Department of Agriculture, Washington, D. C., for his paper entitled "Soil Aldehydes," described by the Sub-Committee as a valuable contribution to the science of agricultural chemistry.

No. 2737: Edward Longstreth Medals of Merit to Dr. Herbert E. Ives, Dr. E. F. Kingsbury and Dr. E. Karrer, all of the Physical Laboratory of the United Gas Improvement Company, Philadelphia, Pa., for their paper entitled "The Physics of the Welsbach Mantle," described by the Sub-Committee as affording a definite indication of both the limitations and possible efficiency of the Welsbach Mantle.

No. 2738: The Edward Longstreth Medal of Merit to Mr. Richard B. Moore, of the United States Bureau of Mines, for his biography and review of the work of Sir William Ramsay, described by the Sub-Committee as a most lucid and informing exposition of the great chemist's life and work.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, March 12, 1919.)

RESIDENT.

MR. J. HOWARD PEW, President, Sun Oil Company and Sun Oil Company, Finance Building, Philadelphia, Pennsylvania.

NON-RESIDENT.

MR. OLAF ANDERSEN, Geologist, Mineralogical Institute, Kristiania, Norway.

MR. HUGH SEPTIMUS GORDON, Mining Engineer, 10 Nevill Court, London, E. C. 4, England.

CHANGES OF ADDRESS.

LIEUTENANT JAMES W. COTTRELL, P. O. Box 302, Hammonton, New Jersey.

CAPTAIN HENRY M. ELLIOTT, Wardman Park Inn, Washington, District of Columbia.

DR. MILTON W. FRANKLIN, Remy Electric Company, Andersen, Indiana.

LIEUTENANT A. H. GFRÖRER, The Automatic Transportation Company, 2933–65 Main Street, Buffalo, New York.

MR. OTTO LUYTIES, Sharon Springs, New York.

LIEUTENANT THOMAS S. MARTIN, 3D, 710 North 41st Street, Philadelphia, Pennsylvania.

MR. W. A. PATTON, Radnor, Pennsylvania.

LIEUTENANT CHARLES E. RICHARDSON, in care of International Coal Products Corporation, 581 Broad Street, Newark, New Jersey.

MR. DWIGHT P. ROBINSON, 49 East 52d Street, New York City, New York.

LIEUTENANT COLONEL W. C. SPRUANCE, 2507 West 17th Street, Wilmington, Delaware.

MR. FRANK A. STANLEY, East Auburn, California.

MR. JOHN STONE STONE, 68 Montague Street, Brooklyn, New York.

NECROLOGY.

James Douglas, LL.D., was born in Quebec, Canada, on November 4, 1837, and died on June 25, 1918. He received his education in his native city and in Germany and Scotland. He was a graduate of Queens and Laval Universities, Canada.

He became interested in mining and metallurgy through his connection with the Harvey Hill mines and other mining properties in Lower Canada. In 1875 he removed to Phoenixville, Pennsylvania, to take charge of the metallurgical operations of the Chemical Copper Company. Five years later he visited Arizona and became active in copper mining. He spent many years in developing mining lands in Arizona, Mexico and New Mexico, and took an active part in the promotion of railroad enterprises throughout these States. For a number of years Doctor Douglas was president of the El Paso and Southwestern Railroad Company, which operates over a thousand miles of standard-gauge road.

His literary labors include "Canadian Independence," "Quebec in the Seventeenth Century," "New England and New France," "Journal and Reminiscences of James Douglas." He contributed many articles to the technical press, and delivered a number of lectures and addresses, including a series of the Cantor Lectures before the Royal Society of Arts of London.

Doctor Douglas was a member of many scientific societies, both in the United States and in Europe. He was twice president of the American Institute of Mining Engineers, and was also a member of the Board of Trustees of the American Museum of Natural History. He was the recipient of the Gold Medal of the Institution of Mining and Metallurgy, and in 1915 was awarded the John Fritz Medal. In 1899 he received the Honorary Degree of Doctor of Laws from McGill University. Doctor Douglas became a member of The Franklin Institute in 1899.

Lewis Sharpe Ware, for nearly forty-two years a member of The Franklin Institute, died in Paris, France, on December 20, 1918.

Mr Ware was born in Philadelphia on June 18, 1851, son of Lewis S. and Elizabeth W. Roberts Ware. He was educated at the Hill School, Pottstown, Pennsylvania, and in 1875 graduated from the École Centrale in Paris. He then became interested in the problem of sugar beet cultivation and the manufacture of beet sugar and made an extensive study of the beet fields of Europe. In 1874 he shipped several tons of beet seeds to the United States for gratuitous distribution among the farmers. Soon after this he returned to his native city, and in 1879 began the publication of *The Sugar Beet*, which was devoted solely to problems connected with the cultivation of this important plant. This publication appeared uninterruptedly for more than thirty years.

Mr Ware became a member of The Franklin Institute on March 16, 1877, and was appointed a member of the Committee on Library in 1880. He was intensely interested in the work of this Committee, and took an active part in the management of the library until 1888. About this time he took up his permanent residence in Paris, and only visited the United States at infrequent intervals. He obtained quarters in the French capital and began the collection of books, pamphlets and magazines relating to sugar and the sugar industry. The library soon began to grow beyond his expectations, and he found it necessary to secure the services of a librarian. In 1911 the work of cataloging had sufficiently advanced to make it possible to issue a list of the French section. This volume numbers 340 pages and contains over 3400 entries.

During the three decades which have elapsed he has been able to gather together the world's publications on sugar and related subjects, consisting of all printed documents, in all languages, from the earliest times to and including the year 1918. This library, to which he has devoted his best energies during a great part of his life, now becomes the property of The Franklin Institute. He has directed that it shall be deposited in the Institute's library and shall be known as the Ware Sugar Library. A sufficient sum of money has also been provided, the income from which is to be applied to the purchase of new books, and to the care, maintenance and preservation of the entire collection.

Mr Ware represented the United States at the Paris Exposition of 1889 and again in 1900; he was United States Commissioner-General to the International Exposition at Liege, Belgium, 1905.

His many decorations include Chevalier Merite Agricole, 1893; Chevalier de la Legion d'Honneur, 1901; Officier Ordre de Leopold; Commandeur Etoile Noire; Officier de l'Instruction Publique.

He was a member of the American Philosophical Society; the Association des Chimistes, Paris; Association des Anciens Élèves de École Centrale, and the Ingenieurs Coloniaux.

His works include "The Sugar Beet," 1880; "Study of the Various Sources of Sugar," 1881; "Production, Requirements and Selection of Sugar Beet Seed," 1896; "Sugar Beet Seed," 1898; "Cattle Feeding with Sugar Beets, Sugar, Molasses, etc.," 1902; "Beet Sugar, Manufacturing and Refining" (2 vols.), 1907.

LEWIS S. WARE
1851–1918

John Sellers Bancroft, member of the Franklin Institute since 1865, died January 29, 1919, after a lingering illness. He was the son of Edward Bancroft and Mary Sellers Bancroft and was born in Providence, R. I., September 12, 1843. His father, who will be remembered as the inventor of the "Ball and Socket Hanger," operated a machine shop in Providence, R. I., in partnership with his brother-in-law, William Sellers, making lathes, planers, drill presses and specializing in shafting and mill gearing.

In 1848 Bancroft & Sellers removed to Philadelphia and in 1855 were located at Sixteenth and Hamilton Streets. On the death of Edward Bancroft, John Sellers, Jr., was admitted to partnership and the firm name was changed to William Sellers & Co.

John Sellers Bancroft graduated from the Central High School in 1861 and became an indentured apprentice in the machine shop of his uncles in that year. He applied himself so assiduously to his duties and developed so much ability that he was made a gang foreman in his nineteenth year and upon completing his apprenticeship, in 1864, was appointed foreman of the machine shop. Two years later, at the age of twenty-three, he became general foreman of the whole establishment, including foundry and smith shop.

He was admitted to partnership in 1873 and upon the incorporation of the firm, in 1886, he was elected a director and general manager. In 1902 he resigned to associate himself with the Lanston Monotype Machine Company as mechanical engineer and manager and later as vice-president and treasurer.

He became a member of the American Society of Mechanical Engineers in 1880, was a manager 1909–1911, and a vice-president 1915–1917.

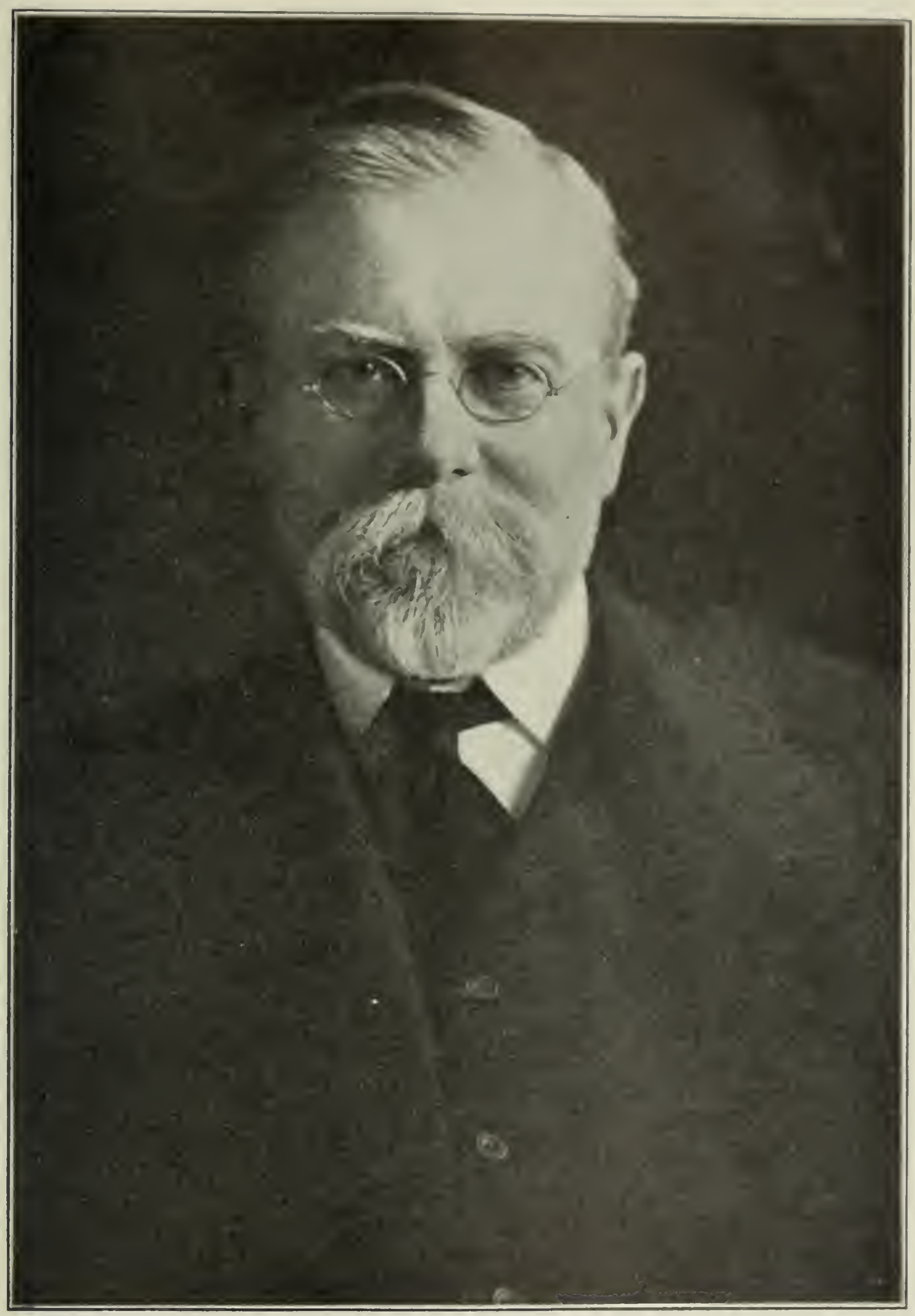
During his long connection with the Franklin Institute he does not seem to have held any office; but he was much interested in its work and served on many committees.

About 1861 his firm introduced into the United States the Giffard Injector for feeding boilers. This was not only a new device but its manufacture required the development of a proper system of methods, tools and fixtures; and in establishing and developing this work, Mr. Bancroft was largely instrumental. Later he concerned himself earnestly with the improvement of the instrument and conducted or directed the tests and experiments upon which the improvements were based.

Perhaps the most conspicuous achievement of his later life was the perfection of the Lanston Monotype Machine. It came to him scarcely more than an ingenious mechanical toy, frail, unreliable and difficult to construct. He superintended its redesign to facilitate its manufacture, located one by one its weak spots, devised corrections, made improvements and developed a system of manufacture which produced a thoroughly practicable substantial machine of much greater scope and capacity than the original; and from a partial failure he evolved a great commercial and mechanical success.

Mr. Bancroft was a mechanic of unusual ability and a fertile versatile inventor, as is attested by the large number and great variety of patents which bear his name. He had high mechanical ideals and strove for the best in method and workmanship. As an executive officer he was a strict disciplinarian, was careful and thorough, and gave close attention to details.

COLEMAN SELLERS, JR.



JOHN SELLERS BANCROFT
1843–1919

Mr. Charles A. Brinley, 247 South 16th Street, Philadelphia, Pennsylvania.

Dr. Charles F. Himes, Carlisle, Pennsylvania.

LIBRARY NOTES.

PURCHASES.

Blanchard, A. H., ed.—American Highway Engineers' Handbook. 1919.
Dana, Gorham.—Automatic Sprinkler Protection. 1919.
Grabau, A. W.—Principles of Stratigraphy. 1918.
Griffiths, Ezer.—Methods of Measuring Temperature. 1918.
Industrial Arts Index. Vol. 6. 1918.
Jackson, J. F. A., comp.—Philadelphia Year Book. 1919.
McCollum, E. V.—The Newer Knowledge of Nutrition. 1919.
Perkin, A. G., and Everest, A. E.—Natural Organic Colouring Matters. 1918.
Photograms of the Year. 1918.
Schuster, A., and Shipley, A. E.—Britain's Heritage of Science. 1918.
Scott, W. W., ed.—Standard Methods of Chemical Analysis. 1918.
Stewart, A. W.—Recent Advances in Organic Chemistry. 1918.

BOOK NOTICES.

Beverages and Their Adulteration, Origin, Composition, Manufacture. Natural, Artificial, Fermented, Distilled, Alkaloidal and Fruit Juices. By Harvey W. Wiley, M.D. 408 pages and index, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1919. Price, $3.50 net.

Food analysts and public health authorities will greet with pleasure the appearance of this work. Few persons are as well qualified as the author to speak with authority on the subject, now especially important in view of the drastic methods that have been adopted to control all habit-forming beverages. Before passing to a review of the text, it is proper to say that the book is an excellent specimen of printing, and is exceptionally free from typographical errors. Those that have been noted are trifling, but Doctor Wiley accidentally "hustero-proterizes"—as Carlyle would say—on page 128, when he states that Charles II failed in his "campaign against coffee, and it was taken up by Oliver Cromwell."

The work is characteristically "Wileyesque." Its author may, indeed, be considered the Roosevelt of American Food Chemistry; earnest and aggressive in what he believes to be the right, fearless in defending his views, whether antagonized by those in high station or low; intensely dogmatic, but sometimes unable to see clearly the other side of the question at issue. Doctor Wiley, however, always speaks from thorough and detailed information; the late ex-President was much more of a generalizer.

The work is not a manual of analysis. Except in the section on "Tea," methods of detecting adulterations are practically lacking. Much space is given to the manufacture of the more important beverages, with elaborate details as to the source and character of commercial wines and brandies, together with a number of formulas for mixed drinks. A matter of particular interest is the adulteration of whisky, a subject upon which there is widespread ignorance and consequent error. In discussing the question of prohibition, no statement is more frequently made by the anti-prohibitionists than that where the licensed saloon is suppressed, highly adulterated and poisonous liquors are sold in the "blind tigers," "speak-easies," etc. An extensive correspondence that I had some years ago with the food analysts of the several States showed no evidence of such adulterations, and Doctor Wiley's book confirms this view, for under the head of adulterations of whisky no mention is made of any poisonous ingredients having been found in it. As the subject is of great present practical importance, it will be worth while to note briefly what is said about it in the book. As is well known to all food chemists, Doctor Wiley took a very active part in the discussion of the question, "What is Whisky?" which arose mainly over the interpretation of a clause in the Federal Food and Drug Act. The question of the poisonous nature of the additions was not prominent, for it was conceded that they were not any more harmful than the alcohol, and, indeed, in most cases not harmful at all. An effort was made to limit the term "whisky" to a distillate from the fermented mash of certain grains, and especially to declare that if the so-called "silent spirit" was added with or without harmless coloring matters—such as prune juice or burnt sugar—the article should be designated "compound," and not merely "blended." Space does not permit even outlining the arguments and developments in the case, but the result was that President Roosevelt and Attorney-General Bonaparte took the extreme view, but President Taft and Solicitor-General Bowers practically reversed these decisions. Doctor Wiley summarizes the present practise of the Federal authorities as follows: "The regulations of the Bureau of Internal Revenue, which control the marking and branding of distilled spirits at the present time (1918), are based on the above opinion, but go much further in validating misbranding and adulterations." One turns, therefore, with especial interest to the paragraphs on whisky adulterations to see what has been the result of this alleged "letting-up" in favor of the trade. Turning to the special item, "Adulterations of Whisky" (page 326), we read: "The adulteration of distilled liquors in all parts of the world has been continuous and extensive. Perhaps there is no other country where adulteration has reached such proportions as in our own." Three types are then enumerated. *First:* Selling raw spirits; that is, freshly distilled whiskies, under guise of age by means of artificial coloring. Burnt sugar (caramel) is the only artificial coloring mentioned in this paragraph, but allusion is made to hastening the coloring process by keeping the whisky hot while in a charred cask. *Second:* Substitution of whisky by a spirit rectified more or less completely, and from which the substances that give to whisky its character have been entirely or in part removed. *Third:* The refilling of bottles which have contained genuine whisky with an adulterated article (presumably adulterated by one of the methods just described) which is still sold under the same name.

This is all. No reference to "stock-in-trade" cries of the liquor element, "rot-gut," "kill-at-forty-paces," "Jersey-lightning." Singularly, there seems to be no reference to the possible use of rectified methyl alcohol as an adulterant; the title is not even in the index. That there is no mention of strychnin and fish-berries need not astonish, for these additions are practically unknown now even if they ever occurred.

Sixty-four pages are devoted to potable waters, including methods of purification, and standards of chemical and bacterial purity. In view of the thoroughness with which these subjects are now presented in special manuals, much of this section seems unnecessary. The author accidentally falls into a contradiction when, in the introduction (page xiii), water is classed as purely condimental; that is, having little or no food value, while on page 1 of the body of the text it is termed an indispensable food. Of the forty-two illustrations, two are of leaves that may be used for adulteration of tea, and twenty-three of scenes in wine-making.

The work contains a large amount of information on one of the most important topics in public hygiene. In the chapter on water there is a discussion of the divining-rod, and scattered throughout there is considerable general literature. Thomas Jefferson's views on the wine-excise are quoted, and many extracts given from old books and essays. Occasionally the author "drops into poetry," or, rather, doggerel.

It is evident that Doctor Wiley has poured his soul into the book, and on almost every page we see the results, both tangible and psychologic, of his long, active, efficient work in connection with the efforts of the authorities to improve the standards of foods and beverages and to protect the mass of the people from fraud and harm. He began work in the days of the primordial chaos of food regulation in this country, and for many years was one of the principal determinants in the investigations. It would be idle to pretend that the present condition is not one of some degree of disappointment, for every one familiar with existing conditions as revealed by the records of our courts, Federal and State, knows that the war against food-fraud is far from won. We can, therefore, easily understand why the book shows the author's emotional reaction to the abuses of which he has seen so much, and against some of which he has valiantly but vainly contended. He can indeed say of the course of American food control,

"quæque ipse miserrima vidi,
et quorum pars magna fui."

HENRY LEFFMANN.

TREATISE ON APPLIED ANALYTICAL CHEMISTRY: METHODS AND STANDARDS FOR THE CHEMICAL ANALYSIS OF THE PRINCIPAL INDUSTRIAL AND FOOD PRODUCTS. By Professor Vittorio Villavecchia, assisted by several collaborators. Translated by Thomas H. Cope, B.Sc., University of Birmingham. Volume II, 528 pages, contents and index, illustrations, 8vo. Philadelphia, P. Blakiston's Son & Company, 1918. Price, $6.

The first volume of this work was reviewed in this JOURNAL some months ago, and much of what was there stated can be stated of the present volume, which completes the work. The book is excellently printed, the translation well done, the arrangement of the subject matter convenient, and the processes given commendable. The present volume covers many important and difficult subjects, among which are meat, milk, flour and related articles, sugars, fermented beverages, rubber and substitutes, tanning materials, inks and coloring matters. Extensive treatment is given of the last-named group, and elaborate tables for the detection of colors under several conditions are presented.

American work seems to have but little interest to the author. Examination of the bibliographic references shows that out of a total of about one hundred and fifty, only four can be considered American. Forty-eight are to German publications and forty-four to Italian. The remainder are to French and British authorities.

The chapter on "Beer" has been re-written by the translator. Under whisky no mention is made of the possible admixture with burnt sugar or prune juice.

The style is concise and clear, and the work will be of great value to the practical analyst. HENRY LEFFMANN.

SURFACE TENSION AND SURFACE ENERGY, AND THEIR INFLUENCE ON CHEMICAL PHENOMENA. By R. S. Willows, M.A., D.Sc., and E. Hatschek. Second edition, 112 pages, contents and index, 21 illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.50 net.

In preparing this second edition, the authors have extended considerably the field to be covered, and have added much matter which they tell us has been suggested by the questions from students and readers. An entirely new chapter (VI) is specially devoted to complex phenomena, among which may be mentioned "Emulsions," "Electrical Theory of Dyeing," "Theory of Tanning," "Origin of Thunderstorms," "Flotation Processes." In the last case, only one process is discussed—that of the "Minerals Separation Company." It appears, however, that much remains to be determined concerning the exact theory of these now much-used processes, for the authors say (pages 104–5): "No general theory of the process has, however, resulted so far, and we can, therefore, only roughly indicate the factors which come into play. The selective adsorption of the oils by the sulphids is a fact which in the present state of our knowledge we have simply to accept." HENRY LEFFMANN.

ANNUAIRE POUR L'AN 1919, PAR LE BUREAU DES LONGITUDES. AVEC DES NOTICES SCIENTIFIQUES. About 700 pages, 14 figures, 5 celestial charts in colors, 3 magnetic charts, 16mo, paper bound. Paris, Gauthier-Villars et Cie, 1919. Price, three francs.

The publication of this annual was instituted by the National Convention on the 7th of Messidor an 3, less than a year after the close of the Terror. The first edition appeared in 1796, and it has been issued regularly to this day. The roar of guns for over four years in "Flanders Fields" has not broken its course. The text is of the same general type as those of former issues and will not need specific mention, but at the request of the publishers the reviewer notes the titles and authors of two original papers that appear in this issue:

Figures d'équilibre relatif d'un liquide homogène en rotation, dont les éléments s'attirent suivant la loi de Newton, by P. Appell.

La détermination interférentielle des diamètres des astres, by Maurice Hamy. HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. Provost Marshal General: Second report to the Secretary of War on the operations of the Selective Service System to December 20, 1918. 607 pages, 8vo. Washington, Government Printing Office, 1919.

U. S. Bureau of Mines: Bulletin 172. Abstract of Current Decisions on Mines and Mining reported from January to May, 1918, by J. W. Thompson. 160 pages, 8vo. Technical paper 96. Fume and Other Losses in Condensing Quicksilver from Furnace Gases, by L. H. Duschak and C. N. Schuette. 29 pages, illustrations, 8vo. Technical paper 191. Central Station Heating; Its Economic Features with Reference to Community Service, by John C. White. 23 pages, illustrations, 8vo. Technical paper 215. Accidents at Metallurgical Works in the United States During the Calendar Year 1917, compiled by Albert H. Fay. 23 pages, 8vo. Technical paper 217. Saving Coal in Steam Power Plants. 8 pages illustrations, 8vo. Washington, Government Printing Office, 1918–1919.

Ontario Bureau of Mines: Twenty-seventh Annual Report, 1918, part I. 265 pages, illustrations, plates, maps, 8vo. Toronto, King's printer, 1918.

A Quick Method of Coping Steel Beams. F. W. HARTH. (*The Iron Age,* vol. ciii, No. 11, p. 694, March 13, 1919.)—A new steel beam method, as employed by a large Pittsburgh structural concern, is not alone interesting but also economical. "Coping" is the term applied to the cutting-away of a beam at the end to conform to the contour of the beam against which it is framed. The old method of coping steel beams is very expensive, involving considerable time and labor, the cost averaging $5 per ton beam weight. A very heavy machine, costing perhaps several thousand dollars is used for this work. It is sometimes located in a building by itself, the motive power being hydraulic. As the machine is stationary, the work must be brought to it, which involves considerable handling of quite heavy pieces.

With the new method, the oxyacetylene flame is used. The work need not be moved in performing the operation, and the cut can be made wherever the stock may be; many of the beams are coped on the freight car just prior to shipment. The cost of coping by the acetylene torch, which entails so much less labor and handling, is rarely more than $1 per ton beam weight, or just 20 per cent. of the cost of machine coping. In order to make it possible to employ the gas flame at any point in a fabricating plant, a pipe-line is run underground with top lines radiating from it. The gas is supplied from a central station and piped to the various points where required most.

CURRENT TOPICS.

The Audion Amplifier. Anon. (*Telegraph and Telephone Age*, vol. xxxvii, No. 5, March 1, 1919.)—For more than twenty years, telephone engineers had sought in vain a repeater or amplifying relay, which would be at once extremely sensitive, free from delicate and frequent adjustments, and yet would amplify every modulation of the human voice without distortion. Without such a relay, a telephone at that time was limited to a few hundred miles. This problem of the telephone relay had baffled all the numberless inventors and engineers in the telephone industry. It was an elusive will-o'-the-wisp which looked so simple, and yet defied their most praiseworthy efforts. So keen did the search become and so hopeless seemed the solution, that an eastern telephone company in the nineties offered one million dollars for a successful telephone relay. The prize was never awarded, or claimed. Almost without exception these telephone engineers and inventors attacked the problem from the same angle. They saw one method which afforded a solution. That was to associate in some manner the elements of the well-known telephone receiver and telephone transmitter or carbon microphone. The method was a mechanical one which always in the final analysis failed.

We are indebted to the " wireless " for the revolution in ideas telephonic which alone enables one to talk from San Francisco to New York. In 1902, Dr. Lee de Forest, in the course of his experiments with wireless detectors, discovered that a heated gas was " sensitive " to weak " wireless " waves, and could constitute a new detector for use in radio-telegraphy. In 1903–04 he made over this principle a genuinely practical detector, possessing a sensitiveness far exceeding that of any previously known wireless receiver. He found that when this device, altogether new to the telephone field, was properly connected in the line between a transmitter and a receiver, the audion amplified the voice currents, giving a reproduction of perfect fidelity without a trace of lag or distortion. The audion amplifier was patented in 1907, but it was not till 1912 that the inventor deemed it sufficiently developed to bring it to the attention of the engineering staff of the American Telephone and Telegraph Company. In 1913 announcements were made that the long-dreamed-of transcontinental line was to become a reality.

The audion amplifier consists of a small incandescent lamp bulb exhausted of air, which contains, in addition to the usual filament, two thin plates of nickel about one-eighth of an inch from the filament on each side. Between the filament and the plates are two pieces of nickel wire bent grid-shaped. The incoming current, to be repeated and amplified, is conducted to the "grid" wire. The outgoing line is connected, one terminal to the plates, the other to the filament. In this circuit is found a battery. A separate battery lights the filament to incandescence. The heated gas becomes then a conductor of the local current from the battery which can pass from the cold plates to the hot filament. That is, negatively charged "carrier," "ions" or "thermions," as they are termed, speed in invisible streams of almost infinite tenuity from filament plates, passing in their migration through the spaces between the wires of the grids. The slightest electrical potential, or charge of electricity impressed upon these grids from the incoming telephonic currents, deflects or retards some of these minute carriers of negative electricity. This effect is always proportional to the cause, so that the current changes produced in the outgoing or "plate" circuit are exactly similar to those current changes or electric charges upon the grid which produced them. In other words, a unit electrical charge delivered upon the "grid" produces a deflection or stoppage of six to ten unit electrical charges passing from the filament to the plates.

The De Forest audion is to-day receiving wireless messages in New York, and at the great naval station at Arlington, Va., from San Francisco; Nauen, Germany; Paris, France, and from the radio stations in the Pacific Ocean. Transoceanic telephony by submarine cable, with numerous Pupin coils and the audion amplifier is theoretically possible; commercially an utter impossibility. The cost of such a cable would be prohibitive. Transoceanic wireless telephony, however, is to-day almost within our reach.

Production of Hydrogen and Water Glass by the Silicol Process. ANON. (*Chemical and Metallurgical Engineering,* vol. xx, No. 6, p. 289, March 15, 1919.)—Several years ago George F. Jaubert described the military methods in use at that time for the production of hydrogen, among which the reduction of water by silicon was of chief importance for military purposes, such as for dirigibles, etc. Siemens and Schuckert were the original investigators and worked out a process for the production of hydrogen from the reaction:

$$Si + 2NaOH + H_2O = Na_2SiO_3 + 2H_2$$

Initially steam was employed, but later it was found that the heat of solution of the caustic was sufficient to start the reaction and that it would maintain itself thereafter. The process was a chemical success, but, due to the high price of silicon, was not economical.

In order to reduce the costs of the pure silicon, Captain H. Lelarge substituted silicon alloys in the process, successfully operating the reaction with a silicon iron containing as little as 18 per cent. silicon. However, the 50 to 80 per cent. ferrosilicons were much preferable. *Engineering*, in its January 24 issue, gives a description of one of the British Admiralty hydrogen gas plants, the production of which in peace times may be utilized in oil refining by the water-glass method and hardening by hydrogenation, offering an outlet for both the sodium silicate and the hydrogen at obnormally low costs.

The plant operates the silicol process, which consists in the decomposition of silicon alloys obtained in the electric furnace, such as ferro- or mangano-silicon, or even silicospiegel, by a concentrated solution of caustic soda (35 per cent. to 40 per cent. of NaOH). In the silicol process, the silicon alloys are made to act on a caustic alkali solution having a high boiling-point, the object being to retain in the solution itself all the heat generated by the reaction in the combination of the silicon with the alkali, thus doing away with all outside heating.

The Rôle of the Catalyst. ANON. (*The Lancet*, through *Scientific American Supplement*, vol. lxxxvii, No. 2254, p. 164, March 15, 1919.)—Chemists long ago discovered the peculiar action of a third party in promoting chemical interaction. It may function equally in the relatively cold or under conditions of high temperature. The remarkable behavior of catalysts in the human body at its normal temperature illustrates the importance of their action in promoting healthy nutrition, which depends upon the complete chemical assimilation of food substances. An early example of catalysis is in the use of spongy platinum, in the presence of which the union of a mixture of hydrogen and oxygen takes place at such a speed that ignition results. The most remarkable catalyst of all is water, without which, it has been shown, combustion or oxidation is impossible.

We have much yet to learn as to the nature of the action of the accessory factors in food—for convenience called vitamines—which serve as antineuritic and antiscorbutic agents. It is conceivable that, in a chemical sense, they act as catalysts—that is, as a third party, rendering the potentialities available for the maintenance and growth of the organism. It is known, at all events, that they occur in quite minute proportions, in spite of which they prove to be essential to growth. When we consider the very remarkable results produced in great industrial processes by the agency of the merest trace of a third party, the catalyst, our views are strengthened as to the importance of a certain factor in however minute quantity. There is good reason for suggesting that the vitamines are catalysts just as are the enzymes, whose action in many respects resembles that of inorganic catalysts, particularly in the colloidal state. Dr. G. G. Henderson, in his recent valuable treatise, "Catalysis in Industrial Chemistry" (Longmans, 1919), says that the term catalysis is now generally used to designate those chemical changes of which the progress is modified by the presence of a foreign substance, and he further points out that it has for a long time been known that the velocity of many chemical reactions, which take place very slowly if the reacting substances alone are present in the system, is greatly increased by the addition of certain substances which have the same composition after the change has been completed as at the beginning, and therefore appear to influence the course of the reaction without taking any definite stoicheiometric part. This definition would appear to include as catalysts all necessary food factors having no direct nutritive value themselves, but serving as promoters of a nutrient consummation.

The application of catalysts in industrial operations is growing very rapidly in importance, and the behavior in many respects of the catalysts employed shows a curious parallel to well-known physiological phenomena. Traces of arsenic, mercury, sulphur, hydrocyanic acid "poison" in many cases the catalysts' activities, and there are also negative catalysts which inhibit the action of positive catalysts, not by "poisoning" them, but by neutralizing their potentialities as acid does an alkali. The advances made and the vista opened up by the study of catalytic action, though confined largely to industrial processes, should persuade biologists, as well as biological chemists—we see no dividing line between these two schools of workers—to accept a cue which followed may lead to results of immeasurable importance in the study of life processes.

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TRANSATLANTIC RADIO RECEPTION.*

BY

MAJOR CHARLES A. CULVER,
Signal Corps, U. S. A.

INTRODUCTION.

WITH the opening of hostilities between the United States and the Central Powers, there arose the physical possibility that the enemy would interrupt the Transatlantic cables. In order to provide for such a contingency, it therefore became necessary to take steps to improve the then existing Transatlantic radio service.

Some time before the United States entered the war the United States Government, through the Navy Department, in the interests of neutrality assumed control of the Transatlantic radio transmitting stations at Sayville, Long Island, and Tuckerton, N .J., these stations having been owned and controlled by German interests.

On October 4, 1917, a conference between representatives of the Navy and War Departments was held at New London, Connecticut "relative to the substitution of radio for cable service in the Atlantic." At this conference a plan was formulated to initiate a system of Transatlantic radio communication "to serve in event of failure of cables between the United States and Europe as brought to attention by the Interallied Protocol, 22, August."

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* Communicated by Maj.-Gen. George O. Squier, Chief Signal Officer, U. S. Army.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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The diagrams shown as exhibit A1, A2 and A3 indicate the general plan of operation decided upon. The transmitting stations at Annapolis, Md., and Marion, Mass., were not at that time completed. Later, New London was abandoned by the Navy Department as a control receiving centre in favor of Belmar, New Jersey. Receiving stations were also established by the Navy at Chatham, Mass., and Bar Harbor, Maine. Washington was not used to any extent for receiving Transatlantic traffic.

Subparagraph 2 of paragraph "F" of the New London Protocol of October 4, 1917, reads as follows:

> "With respect to the three American receiving centers herein recommended, it will be noted that these centers are subject to change if and when better locations are known. In harmony with the suggestion at the end of Paragraph A in the Protocol, plans are now making for the establishment of experimental receiving centers in widely different localities in North America, and perhaps in the West Indies and elsewhere. Therefore, our future course with reference to the number and location of receiving centers will depend upon the result of these proposed experiments."

The above paragraph refers to the proposed joint Army and Navy program for the determination of the most favorable receiving centres. Owing to the fact that Army posts were located at numerous points widely separated throughout the United States, it was obviously practicable for the Signal Corps to take up the matter of determining optimum Transatlantic receiving centres.

It was believed that it would be possible to find several sites so located that, at any given hour of the day, at least one of the stations would be able to make perfect copy, and that by combining the results secured at several stations, an uninterrupted receiving service could be secured. It was appreciated that the British Association Committee for Radiotelegraphic Investigation had collected and analyzed a large amount of data bearing on X's,[1] and also that De Groot had conducted an extensive investigation in the Dutch East Indies bearing on this matter, but it was felt that the problem confronting American radio engineers and scientists was, from the nature of the case, more or less local in character and peculiar to Transatlantic reception on this continent.

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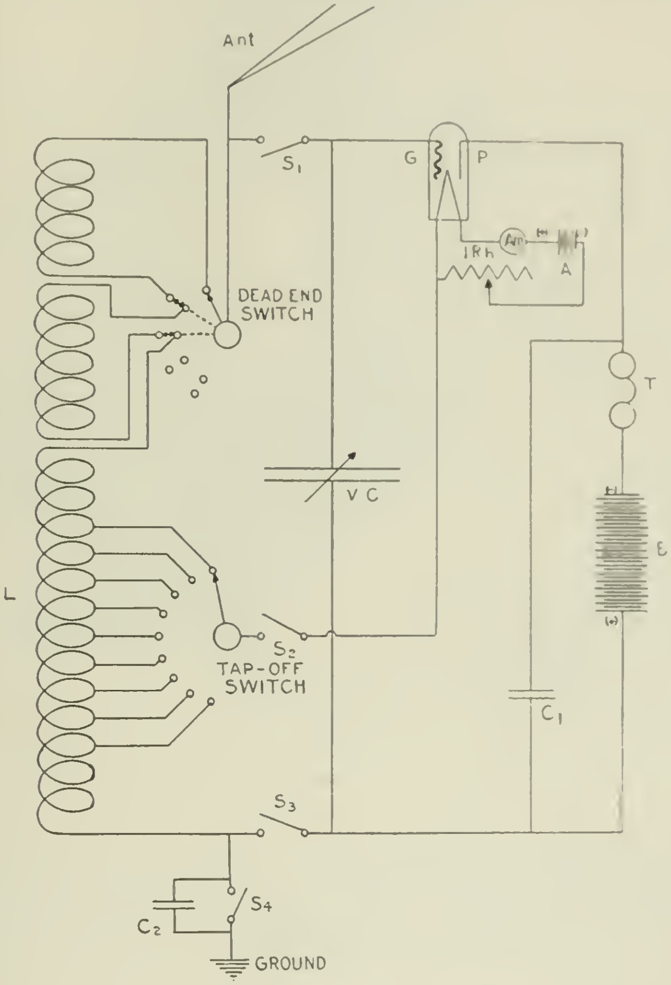
[1] The symbol X will be used throughout this report to indicate any extraneous electrical disturbances, except interference from other radio stations and inductive effects from power lines, and which tend to interfere with radio communication. The terminology will thus be made to conform with the practice of the British Association.

On October 15, 1917, the writer was detailed by the Officer-in-Charge of the Radio Development Section to organize the work of securing the necessary data upon which a decision might be based with reference to such optimum receiving centres. First Lieut. Eugene Sibley was detailed to assist the writer in the organization of the work.

FIG. 1.



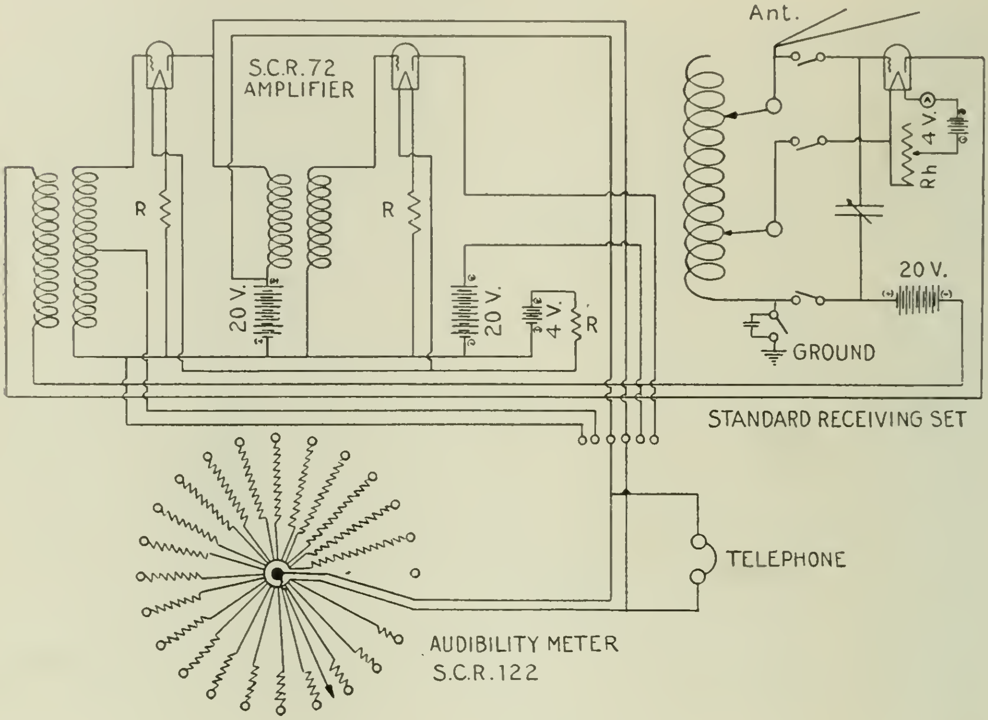
CONDITIONS AND EQUIPMENT.

It was decided to begin the investigation by establishing six experimental Transatlantic receiving stations at suitably located Army posts, with headquarters at Washington, D. C., and steps were immediately taken to secure the necessary personnel and equipment.

The general plan of procedure included not only the taking of audibility measurements on static X intensity and received signal strength during twenty-four hours daily, but, in addition, arrangements were made to secure at all stations simultaneous meteorological records, the purpose being not only to locate optimum receiving centres but, if possible, to determine the factors which govern extraneous electrical disturbances.

Owing to the personal equation of the operators, it was obviously essential that a receiving set should be employed having

FIG. 2.

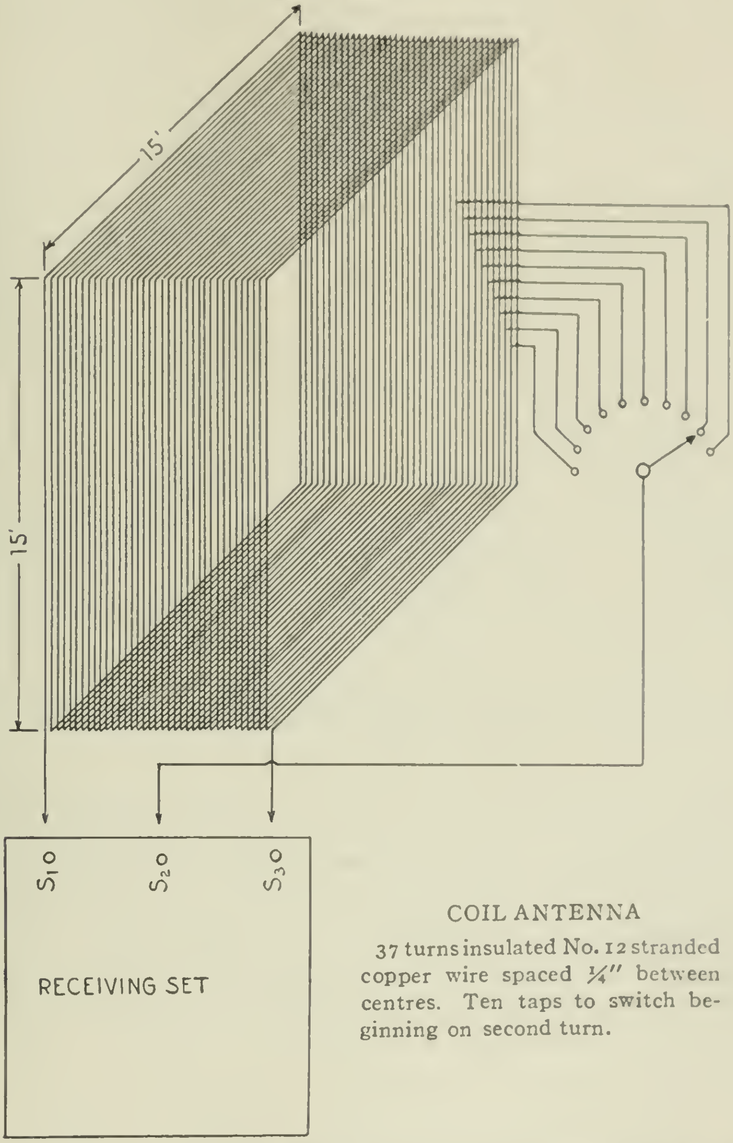


a minimum number of adjustments. Such a set was accordingly designed having only one critical adjustment, and so arranged as to be directly connected to the antenna. A diagrammatic sketch of this receiving set as used is shown in Fig. 1, the variable condenser (0.003 M.F.) being the adjustable element just referred to. The total inductance in the antenna circuit had a value of approximately 14.4 M.H. Standard Signal Corps V.T-1 detector tubes, 20-volt " B " batteries, and telephone receivers were employed. Standard amplifiers, SCR-72, were used in connection with these receiving sets. The shunted telephone method of measuring the audibility of signal strength and X intensity was used. For this purpose, audibility metres made by the General Radio

Company, and reading from unity to 8000, were employed. The complete scheme of connections is shown diagrammatically in Fig. 2.

The antenna system employed in the tests consisted of two horizontal wires, each 1000 feet long (304.8 metres), arranged in the form of a "V," the two wires being separated by an angle of 10° and supported on suitable insulators 15 feet (4.6 metres) above the ground. This particular height was used for physical reasons, as in certain cases it was necessary to extend the antenna across roadways, this being the lowest practical height under such circumstances. The median line between the two wires of the

FIG. 3.

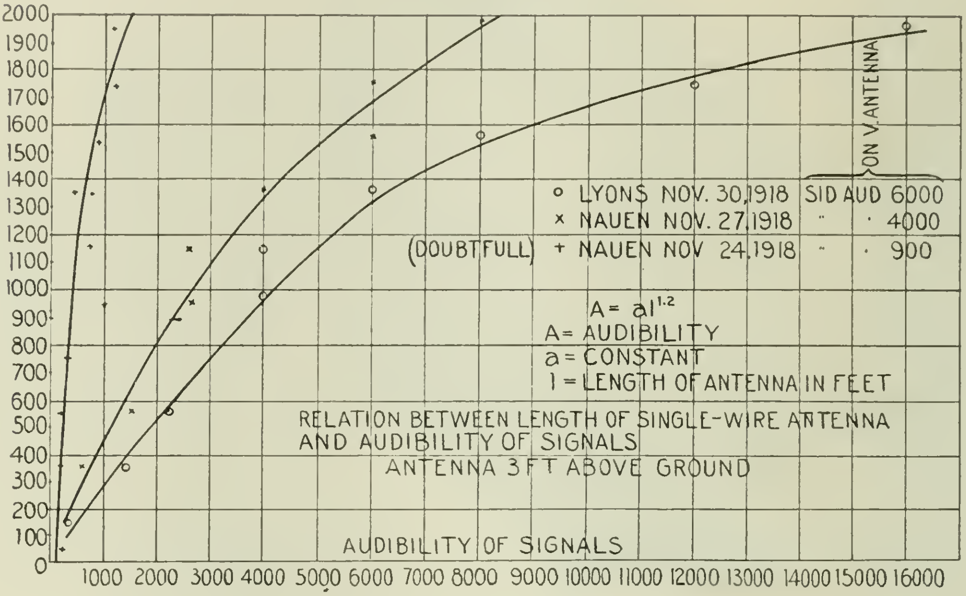


COIL ANTENNA

37 turns insulated No. 12 stranded copper wire spaced ¼" between centres. Ten taps to switch beginning on second turn.

antenna coincided with the great circle joining Lyons, France, and a given receiving station. The antenna wires were placed at an angle with respect to one another in order to partially compensate for any slight error in the determination of the true direction of the great circle. As an example of the functioning of an antenna of the general type used in these tests there is shown in Fig. 4 the relation between the length of a low horizontal one-wire antenna and the energy intercepted, in terms of signal audibility.

FIG. 4.



The mean values of antenna constants are as follows: Fundamental wave length, 1609 metres; capacity at fundamental wave length, 0.00355 M.F.; inductance at fundamental wave length, 0.2026 M.H. A tabulated list of the antenna constants taken when the stations were located as indicated is given in the following table:

TABLE I.

Antenna Constants, Special Radio Receiving Stations.

	Madison	Oberlin	Ithaca	Orono	Rockport	Princeton	Ashland
Wave length (metres)	1620	1520	1735	1594	1610	1515	1670
Capacity (MF)..	0.003428	0.002982	0.003905	0.003078	0.003322	0.002919	0.003623
Inductance(MH)	0.2032	0.2039	0.2044	0.2038	0.2064	0.1938	0.2048

Through the coöperation of the Meteorological Section of the Science and Research Division, a meteorological observer and suitable meteorological equipment were secured for use at the several stations. The following meteorological observations were made, continuous automatic records being secured of the first four factors listed below.

Air pressure
Air temperature
Relative humidity
Soil temperature
Wind velocity
Wind direction
Condition of sky

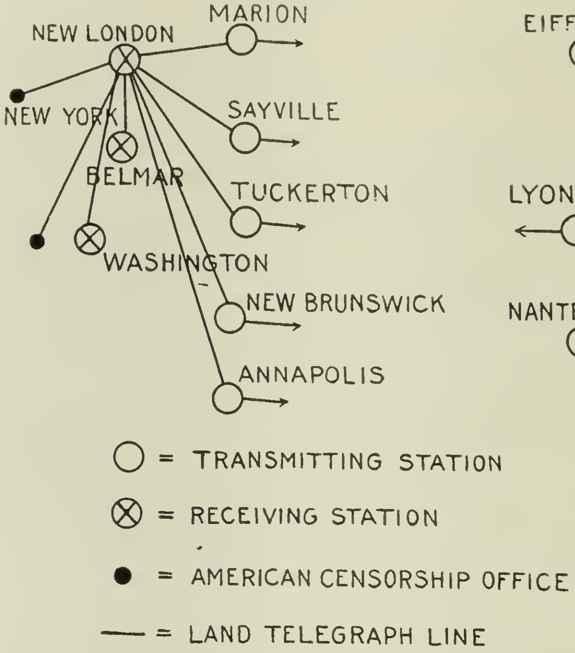
Hourly observations were made on the last three variables mentioned above.

The personnel at each station consisted of a non-commissioned officer in charge, four radio operators and a meteorological observer. A commissioned officer was detailed to supervise the operation of every two stations. Several months were required to properly train the operators in making the necessary observations. As a result the data undoubtedly increased in reliability as the investigation progressed.

As indicated above, the shunted telephone method of measuring audibilities was employed. While it is realized that this method of making observations is comparatively crude and that a large personnel equation necessarily enters into the records, every effort was made to reduce these factors to a minimum. To this end the watches or "tricks" of the operators were rotated and their readings checked; operators were transferred at times from one station to another; receiving sets were also changed. In addition to these measures First Lieut. John A. Riner acted as inspector and visited the various stations from time to time for the express purpose of standardizing the observations, particularly the audibility readings. It is believed that the number of observations made and the length of time during which the investigation was in progress, in part at least, compensates for the inherent inaccuracy of the individual observations.

In determining the relative merits of the various receiving centres, the values of the X-signal ratios are of some value. However, in the last analysis the utility of a given station site was determined by the character of the results in the form of actual copy taken. The Transatlantic traffic from the European stations at Lyons, France (YN); Rome, Italy (IDO); Nantes, France (UA); Carnarvon, Wales (CV), and to some extent Nauen, Germany (POZ), was copied daily and the copy forwarded to the Washington office. Beginning April 1st this copy was carefully compared by an office force trained for the purpose and a daily rating given to each station. By comparison of these results it was possible to determine the net results of the varying receiving conditions on actual traffic. This method disclosed facts which would not have been apparent from an examintaion of the numerical readings on signals and X's alone.

EXHIBIT A1.

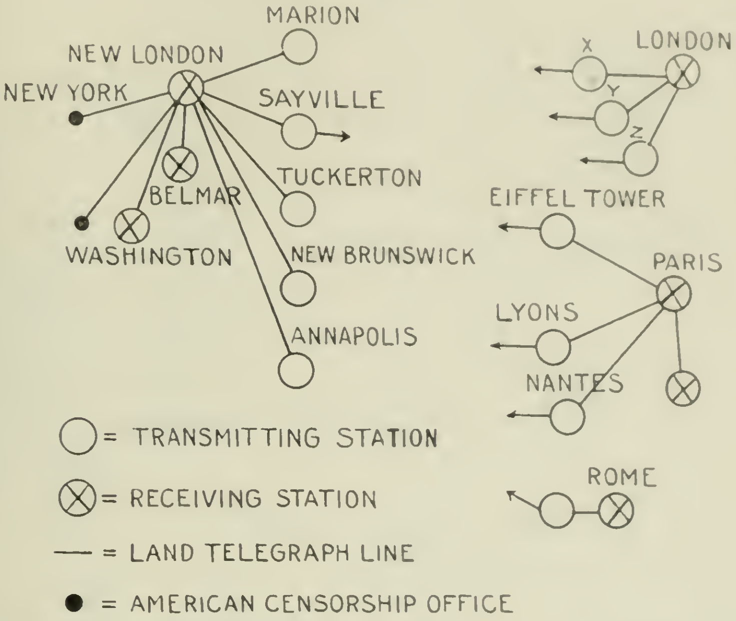


America transmitting. France receiving. Paris designated as chief receiving centre and Lyons designated to send acknowledgments.

A complete list of the various station sites is shown in Table II following, the first six in the list being the first locations investigated. Not more than seven stations were actually making observations under standard conditions at any one time. In selecting the first six sites for investigation it was realized that the Southern locations at Ft. Screven, Ga., and Ft. Brown, Texas, would be unsuitable during the summer months, but it was desired to study the X "Static" conditions at these points. The inland stations were selected with a view not only to studying the relative

X effects but also to note any possible absorption, reflection, or refraction phenomena connected with the signals received from European stations. As soon as it became evident that a given station site was, for any reason, wholly unsatisfactory for Transatlantic reception it was abandoned and the equipment and personnel moved to a new location. If good results were secured at a new site, employing the same equipment and personnel that could not secure such results at a former site, the evidence was reasonably conclusive as to the relative merits of the sites investigated.

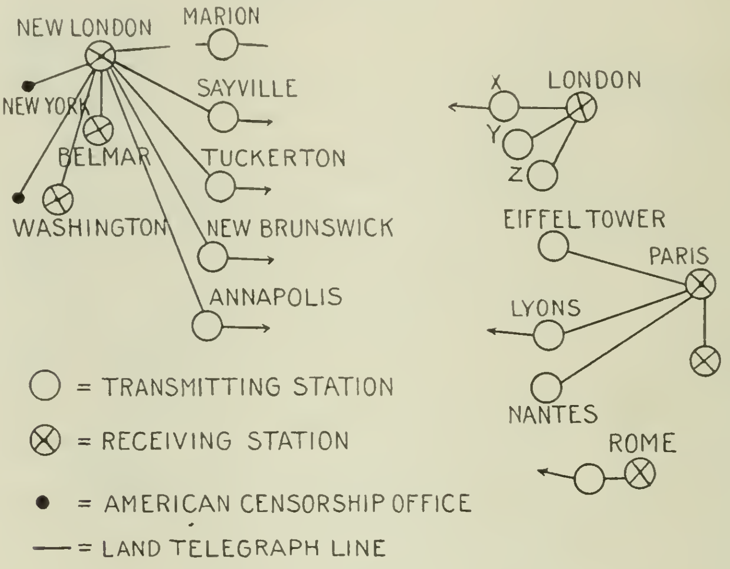
EXHIBIT A2.



England, France and Italy transmitting. America receiving. New London designated as chief receiving centre and Sayville designated to send acknowledgments.

In securing the data, hourly readings on X audibility and half hourly readings on signal audibility were made. Each station was equipped with a high grade timepiece which was carefully regulated and set to keep standard time. The X intensity readings were made with the receiving apparatus set to respond to an 8000-metre wave and also to a 14,000-metre wave. The lower value was taken for the reason that it was of the order of the shortest wave used in long distance work and the higher value was of the order of the longest waves in use. X audibility readings were made when using the detector, one step, and two steps amplification. Signal audibilities were read on one step amplification only. In making the audibility measurements on X's the practice was followed of adjusting the audibility metre until near the point of extinction of sound due to the individual crashes, and if no sound was heard for a period of approximately three seconds the setting of the metre was taken as the reading. After some experience the operators were able to make fairly comparable readings. Owing to the high value of the X intensity during the summer months, and because the audibility metres did indicate values above 8000, the X intensity readings on the detector only, were plotted subsequently to July 1st. All data considered in this report were collected in the year 1918.

Exhibit A3.



America transmitting, England, France and Italy receiving. Chief receiving centres: England, London; France, Paris; Italy, Rome. Stations sending acknowledgments: England, ———; France, Lyons; Italy, Rome.

The daily numerical radio and meteorological data were forwarded to the Washington office and reduced to the form of curves and charts. The curves were so arranged that at any given hour of the day simultaneous conditions at all of the stations could be noted. The data in this form were subjected to careful analysis with the results hereinafter outlined. In passing, it may be of interest to note that more than 1500 separate observations were plotted for each day's record, ten distinct lines of evidence being

TABLE II.

List of Experimental Transatlantic Receiving Stations.

Stations	Location	Date opened	Date closed	Reasons for closing
Fort Monroe	Virginia	Dec. 14, 1917	April 25, 1918	Local radio interference.
Camp Devens	Ayer, Mass	Jan. 1, 1918	May 29, 1918	Local radio interference.
Fort Screven	Near Savannah, Ga.	Jan. 4, 1918	May 19, 1918	High static (X's).
Fort Brown	Brownsville, Tex	Jan. 16, 1918	April 24, 1918	High static. Very weak signals.
Fort Leavenworth	Kansas	Jan. 2, 1918	April 2, 1918	High static. Weak signals.
Fort Snelling	Minnesota	Jan. 26, 1918	June 3, 1918	High static. Weak signals.
University of Maine	Orono, Maine	Jan. 27, 1918	Oct. 15, 1918	Radio survey showed better static signal ratio at Van Buren.
Oberlin College	Oberlin, Ohio	Feb. 25, 1918	Nov. 26, 1918	Investigation discontinued.
University of Michigan	Ann Arbor, Mich.	May 11, 1918	Aug. 5, 1918	High static. Very weak signals.
Ashland	Near Richmond, Va.	May 11, 1918	Nov. 2, 1918	Unfavorable static signal ratio after July 1.
University of Wisconsin	Madison, Wis.	June 9, 1918	Nov. 3, 1918	High static and weak signals from Lyons and Carnarvon.
Rockport	On Cape Ann, Mass.	June 16, 1918	Nov. 26, 1918	Investigation discontinued.
Princeton University	Princeton, N. J.	June 18, 1918	Nov. 26, 1918	Investigation discontinued.
Cornell University	Ithaca, N. Y.	June 20, 1918	Nov. 26, 1918	Investigation discontinued.
St. Mary's College	Van Buren, Maine	Nov. 3, 1918	Nov. 26, 1918	Investigation discontinued.
Sault St. Marie	Michigan	*		
Maryland State Agricultural College	College Park, Md.	*		

* NOTE.—Stations at these sites were installed but were not put into commission owing to investigation being discontinued.

recorded for each station. The curve sheets were thirty inches wide and totalled 270 feet in length. The reduced photostat copies are more or less unsatisfactory, as the original curves were plotted on a larger scale and in colors, therefore it has been considered inadvisable to include them in this article. The original curves and data are on file in the office of the Chief Signal Officer, the curves and charts being packed in a box marked STARS (meaning Special Transatlantic Receiving Stations), Case No. 1, and the data and copy sheets in a box labelled STARS, Case No. 2.

COMPARISON OF X INTENSITY WITH VARIOUS METEOROLOGICAL FACTORS.

Following is a record of the comparisons made between the meteorological factors and X intensity:

In the majority of cases the value of X intensity or audibility, 50 per cent. above the mean weekly or monthly value and 50 per cent. below the same mean, was considered high and low X intensity respectively. In one or two cases, double the mean value was used as a high X value. The 50 per cent. values just referred to are probably more nearly rational than the 100 per cent. value, and are based on a consideration of the ratio between the audibility of the X's and signal strength encountered in practice. It was found that if the X/S ratio became equal to three, the copy began to be imperfect and higher values at this ratio gave increasingly broken copy. The character of X disturbances is, of course, an important factor, but unfortunately cannot be given numerical representation. The 50 per cent. increase of X audibility over the mean value for a given period usually resulted in a ratio of X/S of at least 3 and hence is believed to be a fairly satisfactory basis for comparison purposes.

In compiling the tables which follow the X audibility on the 14,000-metre wave was used, unless otherwise noted. In those cases in which the X intensity and the value of the meteorological factor under investigation were both high or both low at a given time, with respect to a specified norm they were considered to be opposite departures. The numbers in the tables indicate the number of occurrences or counts under the conditions specified.

In the comparisons which follow, certain stations were selected during certain periods, because of the fact that various circumstances connected with the operation of the stations gave evidence that the data during that particular period and at that special place was best adapted to the particular factors being studied. The moving of the stations from time to time to new sites also necessarily limited availability of data during a certain period.

BAROMETRIC PRESSURE.

In considering the possible effect of barometric pressure on the presence and intensity of X's, the records of the three stations—Ithaca, N. Y., Devens, Mass., and Monroe, Va.—were examined over a period of several months. In the case of the two stations first mentioned, the mean X audibility and barometric pressure for the entire period was used as a basis. In the case of Monroe, the weekly mean value of X audibility and the monthly mean value of the barometric pressure were used. In making this comparison, cases of marked departures in X audibility were noted and the corresponding barometric conditions investigated. Fifty per cent. above the mean and 50 per cent. below the mean X audibility were considered high and low values respectively. The mean barometric pressure plus .2 inches (5 mm.) was considered high barometric pressure, and the mean pressure less .2 inches as low barometric pressure. A preliminary series of comparisons was made, using different ranges of barometric pressure, and it was found that the limits just mentioned were the most rational. Table III embodies the results of the comparisons above outlined.

TABLE III.

Comparison Between Extreme Values of Audibility of X's and Barometric Pressure.

	Camp Devens, Mass. Apr. 1 to May 28	Fort Monroe, Va. Mar. 4 to Apr. 20	Ithaca, N.Y. July 15 to Sept. 1
Similar departures from mean values	194	159	49
Opposite departures from mean values	303	140	25
When barometric pressure was at mean value audibility of X's was low	460	201	343
When barometric pressure was at mean value audibility of X's was low	297	129	177

It will be noted from the examination of Table III that there appears to be no particular agreement between X audibility and barometric pressure, with the possible exception that there were more cases in which the X audibility was low than those in which the barometric pressure was at the mean value.

Another comparison between barometric conditions and the interference due to extraneous electrical disturbances was based on the grade of the copy obtained at the several special receiving stations. It is noted elsewhere that the daily copy received at the several stations was carefully read, compared, and a relative grade given to the same, due regard being given to the individual ability of the various operators. The copy taken at Orono, Maine, Rockport, Mass., Ithaca, N. Y., and Ashland, Va., between June 1 and November 15 served as a basis for this comparison. The meteorological condition with respect to barometric pressures and precipitation, as indicated on the United States daily weather map for the day on which the copy was decidedly good or decidedly bad was noted. Table IV sets forth in condensed form the results of this comparison.

TABLE IV

Comparison of Grade of Copy and General Barometric Conditions.

	Orono		Rockport		Cornell		Ashland		Totals	
	Good	Bad	Good	Bad	Good	Bad	Good	Bad	Good	Bad
High pressure area........	5	9	5	10	7	3	8	9	25	31
Low pressure area.........	2	4	2	2	1	2	3	3	8	11
Normal pressure..........	7	6	10	10	9	15	7	11	33	42
High pressure area accompanied by precipitation .	2	3	2	2	3	4	3	2	10	11
Low pressure area accompanied by precipitation .	11	11	3	13	7	10	2	6	23	40
Normal pressure accompanied by precipitation .	2	10	5	6	5	8	6	11	18	35
High pressure area approaching.............	2	3	1	2	0	1	2	0	5	6
Low pressure area approaching..............	0	0	1	1	0	3	0	4	1	8

An examination of the number of instances at each station and also the totals appears to indicate that there is no agreement between barometric pressure and the interfering character of the X's. In addition to the above comparison, note was also made of the barometric condition over the ocean off the coast of Newfoundland. This comparison is shown in Table V.

It may be noted that in the majority of cases a condition of general X interference resulting in poor copy obtained at all stations when a high pressure area existed off the Newfoundland Coast, and that in the greater number of cases good copy was received at all stations when a low pressure area existed off the Newfoundland Coast. As the majority of storm centres which travel over the eastern United States pass out to sea in the general region of the north Atlantic Coast, it would appear from the figures there may be some general relation existing between general barometric conditions over the eastern part of the United States and the attendant atmospheric electrical conditions which result in more or less interference to radio traffic. The details, however, of this relation, if indeed one exists, are not evident.

WIND DIRECTION.

A preliminary examination of the data from the station at Camp Devens with reference to any possible relation which might exist between the direction of the wind and the intensity of the extraneous electrical disturbances, did not show any clear relation between these two factors for that particular station.

TABLE V.

Barometric Condition on Ocean off Newfoundland Coast.

	Good copy at all stations	Poor copy at all stations
High pressure area	8	23
Low pressure area	16	11
Normal pressure area	8	12

A similar examination of the data secured at the Fort Brown Station for a period extending from March 7 to April 24 also does not show any particular relation between the direction of the wind and the X audibility. A more or less complete examination of the wind direction data for all stations is set forth in Table VI.

An examination of this table would appear to indicate that, in general, the X audibility does not bear a definite relation to the direction of the wind. It will be noted that in those cases in which the X intensity was high, and also in those in which it was low, the greatest number of counts for wind direction fall opposite southwest, northwest and northeast. The results at the particular stations were not identical, differing somewhat from the general results.

A comparison was made between the wind velocity and the X audibility on an 8000-metre wave for the month of May at the station at Camp Devens. By inspection it was found that there were 7 similar radical departures from the mean values and 13 opposite departures. In 18 cases when the wind velocity was at the mean value, X audibility was low, and only 1 case when it was high. For this particular place, the figures would appear to indicate that when the wind velocity had a mean value or above, the X intensity was low. In this connection, it should be noted that in the majority of cases examined at this station, the highest point of the wind velocity occurred an hour or possibly two after the lowest point of X audibility.

A comparison similar to the above was made of the data secured at the Fort Brown Station for a period between March 7 and April 24, radical departures from the mean value of the X intensity on an 8000-metre wave being noted by inspection. Sixty-three cases were examined. There were 10 similar departures from the mean values and 10 opposite departures. In 10 cases when the wind was at the mean value, the static was low, and in 15 cases, high. The results at this Station appear to fall into line with those at the Devens Station. An examination of the Fort Brown data for March 1 to April 24 for 14,000-metre wave setting was also made. In this comparison, all those cases in which the X intensity had the value of 8000 or where it dropped to 350 audibility or below, were noted. The mean velocity of the wind during this period was 8.4 miles per hour. A total of 298 cases were examined, in 248 of which the X intensity had a value of at least 8000, and in 50 of which it had a value of 350 or below. Of these cases, there were 42 similar departures from the mean and 66 opposite departures. Thus, it is seen that the data examined on the above indicated basis points to the same general conclusion as previously noted.

A more comprehensive examination of the wind velocity data at all of the Stations was also made. In this investigation, not only simultaneous radical changes of X intensity and wind velocity were considered, but also those cases were noted in which the highest or lowest point of a change in wind velocity occurred within a period not to exceed two hours of a radical X intensity change. The mean monthly wind velocity was used, except for March. Results of this examination are set forth in Table VII.

An examination of the data set forth above likewise points to the conclusion that X audibility tends to vary inversely as the wind velocity, there being 213 opposite departures from the mean compared with 145 similar departures.

TABLE VI.

X Audibility Versus Wind Direction.

	Devens	Rock-port	Monroe	Ashland	Scriven	Prince-ton	Snelling	Cornell	Leaven-worth	Madison	Brown	Totals
	Mar. 4 to May 29	June 17 to Aug. 1	Mar. 4 to Apr. 26	May 22 to Aug. 1	Mar. 5 to May 19	June 18 to Aug. 1	Mar. 9 to May 30	June 20 to Aug. 1	Mar. 7 to Apr. 3	June 11 to Aug. 1	Mar. 7 to Apr. 24	
When audibility was low, wind was in N	3	2	12	2	2	1	7	3	1	1	2	36
NE	17	2	4	3	4	1	3	1	2	1	7	45
E	5	1	7	1	8	3	7	0	1	2	1	36
SE	2	1	1	0	1	0	3	5	0	2	12	27
S	3	2	7	6	4	1	5	4	1	7	5	45
SW	19	6	12	11	9	1	5	6	8	5	6	88
W	12	1	3	7	2	0	4	3	0	6	0	38
NW	8	5	4	14	1	1	8	9	2	2	2	56
Calm	0	0	0	13	0	0	1	0	0	0	0	14
When audibility was high, wind was in N	5	1	6	2	1	1	7	1	3	4	1	32
NE	8	6	1	7	5	1	9	4	0	0	3	44
E	6	0	5	3	3	1	5	4	0	2	1	30
SE	3	0	4	10	4	0	6	2	0	2	12	43
	4	0	6	0	3	3	6	2	0	4	8	36
SW	14	0	15	16	9	3	8	2	4	5	3	79
W	12	1	3	4	2	0	4	3	1	2	0	32
NW	8	0	6	5	5	0	11	9	2	1	0	47
Calm	0	0	0	9	0	1	0	0	0	0	0	10

AIR TEMPERATURE.

The possible relation of air temperature to extraneous electrical disturbances was investigated for all stations covering a period from March 1 to August 1, 1918. In this comparison monthly mean temperature values and weekly X audibility values were used as a basis. Double the mean weekly value of X audibility was considered high and half the mean value as low. Six degrees above the mean temperature value and six degrees below were considered high and low temperature values respectively. Table VIII shows the number of cases of decidedly high or low values of X audibility as they occur in order from day to day, together with corresponding air temperature conditions.

From the table it will be noted that, in the majority of cases, at the time the air temperature stands at the mean value or above the mean value the X audibility is low. It is evident that this relation does not hold at all stations listed, as, for example, at Rockport and Princeton.

SOIL TEMPERATURE.

A preliminary comparison of the soil temperature (25 C.M. beneath the surface of the earth) and the X audibility data secured at Ashland, Devens and Brown did not yield concordant results. The changes in soil temperature were found to take place too slowly to account for the frequent marked changes in X intensity. However, this factor should be studied further, particularly with reference to signal strength.

SKY CONDITIONS.

It is frequently reported by radio operators that they can forecast or predict the possibility of unusually heavy X disturbances by observing the condition of the sky, particularly with reference to the character of the clouds. In order to check this more or less popular opinion, an examination was made of the sky conditions at several of the Transatlantic receiving stations in connection with existing X disturbances.

The following table sets forth the results of the observations at Fort Brown covering a period from March 18 to April 24.

A more complete examination of the data with reference to sky conditions was made in connection with the operation of the sta-

TABLE VII.

X Audibility Versus Wind Velocity.

	Devens	Rock-port	Monroe	Ashland	Scriven	Prince-ton	Snelling	Cornell	Leaven-worth	Madison	Brown	Totals
	Mar. 4 to May 29	June 17 to Aug. 1	Mar. 4 to Apr. 26	May 22 to Aug. 1	Mar. 5 to May 19	June 18 to Aug. 1	Mar. 9 to May 30	June 20 to Aug. 1	Mar. 7 to Apr. 3	June 11 to Aug. 1	Mar. 7 to Apr. 24	
Similar departures from mean values..........	23	7	23	2	10	7	18	8	7	6	10	145
Opposite departures from mean values..........	33	6	29	25	19	5	38	22	8	9	19	213
When the wind velocity was at mean value, X audibility was low....	36	10	22	28	16	3	19	15	4	16	19	188
When the wind velocity was at mean value, X audibility was high....	37	5	23	35	18	4	24	12	6	15	15	196

TABLE VIII.

Table Showing Comparison Between Extreme Values of Audibility of X's and Air Temperature.

	Camp Devens, Ayer, Mass. Mar. 4 to May 29	Rock-port, Mass. June 17 to Aug. 1	Fort Monroe, Va. Mar. 4 to Apr. 22	Ashland, Va. May 13 to Aug. 1	Fort Scriven, Georgia. Mar. 4 to May 7	Prince-ton, N. J. June 20 to Aug. 1	Fort Snelling, Minn. Mar. 4 to June 3	Ithaca, N. Y. June 20 to Aug. 1	Fort Leaven-worth, Kans. Mar. 4 to Apr. 3	Madison, Wis. June 29 to July 21	Fort Brown, Texas. Mar. 4 to Apr. 25	Oberlin, Ohio. July 6 to Aug. 1	Totals
Similar departure from mean values.........	167	26	152	220	50	42	229	80	57	73	46	38	1181
Opposite departure from mean values.........	255	7	150	267	66	24	353	122	96	71	160	70	1641
When temperature was at mean value audibility of X's was low........	187	29	125	264	147	37	222	131	21	92	207	67	1528
When temperature was at mean value audibility of X's was high.......	65	0	60	125	18	11	86	34	5	22	76	27	529

tions at Ithaca, New York, and Princeton, N. J., covering the months of August, September and October. In making this examination, the normal hours of maximum and minimum X audibility were first determined. Whenever the maximum or minimum X audibility did not occur at these hours, it was considered abnormal. Fifty per cent. above the mean value was considered high, and 50 per cent. below the mean value, low.

It is evident from the foregoing data that, at least, on the basis underlying this comparison, no definite relation can be found to exist between the condition of the sky and abnormal X audibility values.

TABLE IX.

X Audibility Versus Sky Conditions.

Sky condition	Low audibility	High audibility
Blue sky	13 times	59 times
Partly cloudy	12 times	25 times
Full cloudy	25 times	164 times

In order to further investigate the possible effect of the sky condition on extraneous electrical disturbances, a comparison was made between the condition of the sky and the grade of copy received at the stations located at Orono, Rockport, Ithaca, and Ashland, covering the months of August, September and October. Only the records for such days were examined which showed distinctly good or poor copy, the general cloud effects and tendencies to become clearer or more cloudy being noted. The results of this examination are recorded in Table X.

TABLE X.

Table Showing Comparison of Grade of Copy and Sky Condition.

Condition of sky	Orono		Rockport		Ithaca		Ashland		Totals	
	Good	Poor	Good	Poor	Good	Poor	Good	Poor	Good	Poor
Blue sky	1	2	3	7	5	4	1	4	10	17
Clouds becoming lighter	9	5	10	8	8	10	10	9	37	32
Cumulus clouds	2	5	1	0	4	6	2	1	9	12
Clear changing to dense clouds	6	8	6	7	1	6	8	6	21	27
Clear changing to rain	1	0	1	4	0	1	2	5	4	10
Rain, dense clouds	7	13	1	8	5	11	5	11	18	43
Rain, becoming clear	1	1	3	5	2	2	0	0	6	8

It is also evident from an examination of the foregoing data that no definite relation appears to obtain between the condition of the sky and intensity of extraneous disturbances as indicated by the grade of copy obtainable, the exception, however, being noted that rain accompanied by thunder and lightning usually resulted in poor copy.

ABSOLUTE HUMIDITY.

A careful study was made of the absolute humidity and its possible relation to extraneous disturbances at the Station in Massachusetts from March 18 to July 1. From the daily meteorological data collected at these stations, the absolute humidity was computed and a curve of the same plotted. A comparison of this curve with the static audibility curve showed 133 similar departures from the mean values and 100 opposite departures.

A second comparison was made of the X audibility and absolute humidity at the above-mentioned station on the basis of similar and dissimilar changes in the respective curves.

On this basis it was found that there were 275 similar cases and 309 opposite changes.

A study was also made of the absolute humidity data resulting from the observations at the Station at Ithaca, N. Y. In comparing the absolute and X curves, a mean weekly value of the X audibility was used, 50 per cent. above and 50 per cent. below this mean being considered high and low respectively. The mean monthly value of the absolute humidity plus and minus one grain was used as high and low humidity respectively.

This comparison yielded the following results:

Similar departures from mean values	126
Opposite departures from mean values	148
Absolute humidity was at mean value when static was low...	162
Absolute humidity was at average value when X audibility was high	107

From an examination of the results of the above comparisons, it would appear that there is little relation between absolute humidity and X intensity.

RELATIVE HUMIDITY VERSUS X AUDIBILITY.

Though the investigation with reference to absolute humidity was more or less indecisive, an examination of the relative humidity records resulting from the operation of the several stations yields a relation which is interesting and possibly significant.

In making this comparison, the fifty-fifty X intensity limits, and the mean monthly value of relative humidity, plus or minus 10 per cent., was taken as a basis of comparison. Table XI shows the results of this comparison.

At all of the 12 stations examined, with the exception of Princeton and Rockport, the X intensity and relative humidity show a marked tendency to vary together. This is also apparent from the totals, which show a large excess of similar departures from the mean values. With reference to Princeton and Rockport, the values of both relative humidity and X intensity were very high, so high in fact, that owing to the limits of the audibility metre, there were few values above the mean available.

Another consideration in this connection is that the results of the observations at the Princeton Station in several of the relations examined failed to be concordant with the results at the other stations.

The marked similarity between the changes in X audibility and relative humidity is even more strikingly shown by an examination of the original curves setting forth the daily observations at the various stations. The diurnal variation in relative humidity corresponds quite closely in many cases to the diurnal variation in X intensity. It is evident that, either X intensity varies directly as the relative humidity, or that both of these variables depend upon a third common factor.

OBSERVATIONS DURING TOTAL SOLAR ECLIPSE.

An expedition was sent to Boulder, Colorado, for the purpose of making observations in signal and X audibility during the period of the total solar eclipse on June 8, 1918, with a view to determining, if possible, the effect of the approaching and departing shadow upon the strength of signals and the intensity of extraneous electrical disturbances.

An antenna of the standard type used at the other stations was erected in open meadow land, entirely devoid of trees and sloping upward to the south, and went toward the mountains, the

TABLE XI.

X Audibility Versus Relative Humidity.

Data	Devens	Rock-port	Monroe	Ashland	Scriven	Prince-ton	Snelling	Cornell	Leaven-worth	Madison	Brown	Oberlin	Totals
	Mar. 4 to May 29	June 16 to Aug. 1	Mar. 4 to April 25	May 11 to Aug. 1	Mar. 4 to May 19	June 18 to Aug. 1	Mar. 4 to June 3	June 20 to Aug. 1	Mar. 4 to April 2	Mar. 4 to April 24	Mar. 4 to April 24	July 3 to Aug. 1	
Similar departures from mean values.	364	8	271	427	84	52	364	178	81	115	206	94	2244
Opposite departures from mean values.	190	24	170	277	49	59	219	102	53	55	171	43	1112
Relative humidity was at mean value when X audibility was low.	109	12	115	117	107	23	227	73	26	86	78	65	1038
Relative humidity was at mean value when X audibility was high.	29	0	53	53	5	10	104	16	15	3	28	11	327

apex of the V antenna being toward the station at Lyons (YN). While the altitude of the locality was high, sharp granite mountains rose sheer from the plain to a height of three to four thousand feet to the south and west, and at a distance of not more than three-fourths of a mile. To the north and east is rather level prairie. The whole region is rather arid, cultivation being carried on by irrigation. The soil is talus from the mountains, and seems very porous and rocky in the immediate vicinity of the station.

The naval station at San Diego, Cal. (NPL), arranged to transmit special test signals on a 13,300-metre wave according to the following schedule:

Denver Summer Time.

4:10 to 4.15 P.M.
4:20 to 4:30 P.M.
4:40 to 4:45 P.M.
4:55 to 5:00 P.M.
5:10 to 5:15 P.M.
5:20 to 5:25 P.M.
5:35 to 5:40 P.M.
5:50 to 5:55 P.M.
6:05 to 6:10 P.M.
6:20 to 6:30 P.M.

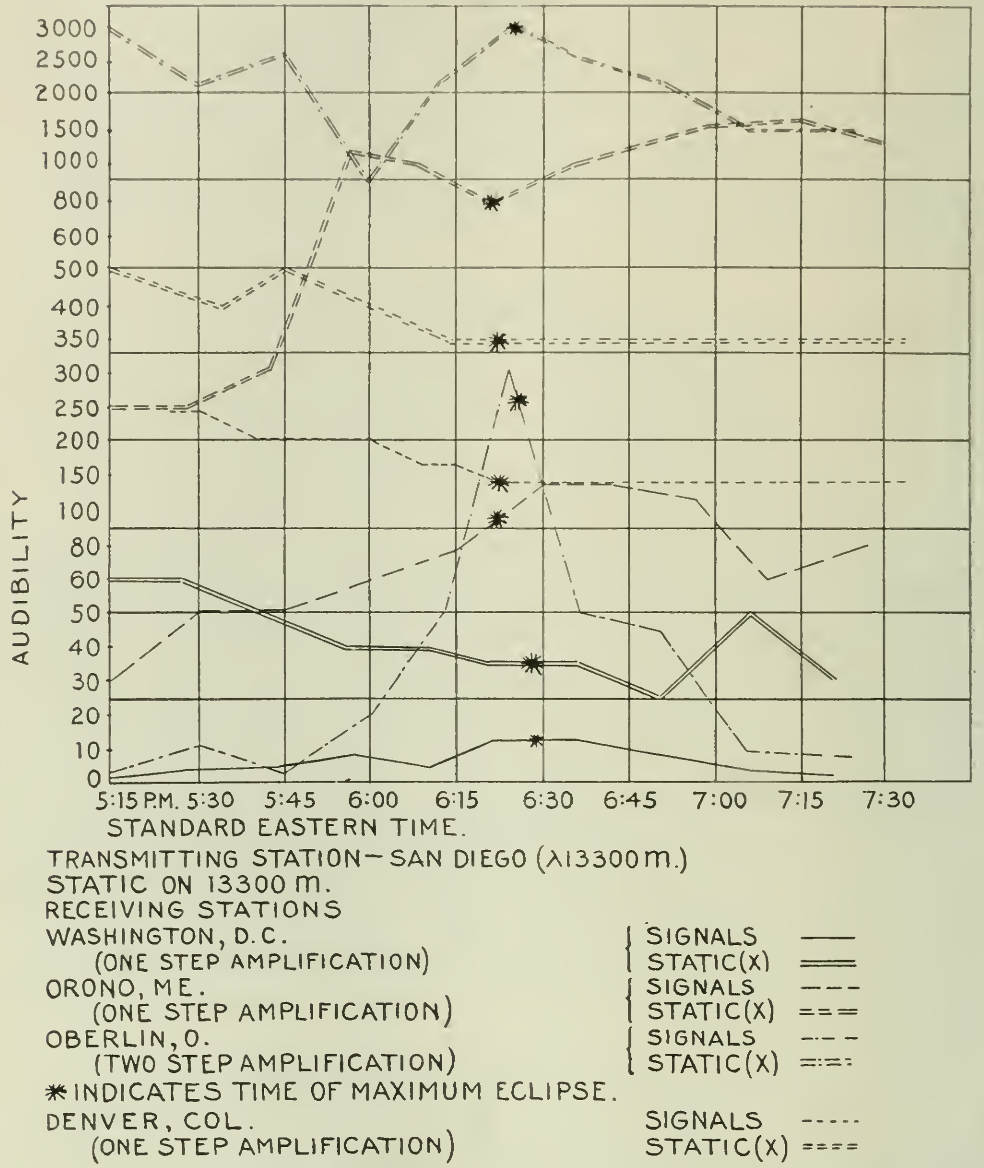
The middle of totality occurred at 5 hours, 22 minutes, 28 seconds.

Using a special portable receiving set, observations were begun at 12.30 P.M. on June 8, readings being made every 30 minutes until the time of the eclipse was reached, when more frequent observations were made. Unfortunately at 2 P.M. storm clouds gathered over the mountains to the west and gradually swept around to the south in the afternoon. The sky became completely clouded during the afternoon and continued so during the period of the eclipse. A direct view of the sun was not possible, though just at the moment of totality a slight clearing of the clouds permitted a view of the sun through a veil of cirrus clouds. Observers connected with the University of Colorado reported an excellent view of the corona.

The approach of a thunderstorm very soon after mid-day on the day of the eclipse caused a marked rise in X audibility, the lightning flashes producing crashes loud enough to be heard at considerable distances from the telephone receivers. As a result it was impossible to hear any Transatlantic signals, if indeed they would have been audible otherwise. Signals from NPL and Tuckerton (NWW) could be heard and identified.

Though an increase in signal strength might have been expected during the period of totality, no such increase was observed, and circumstances were such that all readings made on the signals from the station at San Diego could be checked. In fact, the audibilities taken show an actual decrease, though the decrease is so small as to be accountable on the basis of an error of observation. The gradual and persistent decrease in signal strength, however, up to the time of totality, would appear to indicate some cause other than accident. Late in the evening of the same day the signal audibility was higher than that observed during the

EXHIBIT E.



Effect of partial eclipse of the sun, June 8, 1918, on strength of static and signal audibilities.

afternoon preceding the eclipse. X audibility readings show a change during the afternoon, but the movement of the storm would naturally account for the changes noted, and as a result would mask any change in X audibility due to the passing shadow.

During the time of the eclipse audibility readings were also made on the signals from the San Diego station at the special receiving station, located at Orono, Ashland, Oberlin and Washington, these stations being in the partial shadow. The data secured at the receiving stations just mentioned appear to show a rise in the audibility during the maximum shadow.

The data secured at Boulder, Col., and at the other receiving stations are shown in the curves as Exhibit E.

Considering the observations made during the eclipse as a whole it may be stated that the results are indecisive with respect to the effect of the shadow upon signal strength and extraneous electrical disturbances, though it may be noted that signal strength at stations in the partial shadow shows an increase at or about the time of maximum shadow.

POTENTIAL GRADIENT OF THE AIR.

A preliminary investigation was conducted in order to determine whether any possible relation existed between the potential gradient of the air and local extraneous disturbances.

The Department of Research in Terrestrial Magnetism, Carnegie Institution, Washington, furnished a series of photographic curves showing the continuous potential gradient as recorded in their Laboratory at Washington, D. C., for the first nine months of 1918.

The nearest special receiving station to Washington was the one located at Ashland, Va., distant approximately 100 miles. It was realized that the potential gradient would probably be different in Washington than at Ashland. But it was considered advisable to make this preliminary study of the potential gradient as a factor. X audibility was the basis of comparison, 50 per cent. above the mean weakly X audibility value was considered high X and 50 per cent. below the mean value, low X.

The mean monthly value of the potential gradient was determined in arbitrary units. In computing this mean value the potential gradient for the month of July was not considered, owing to certain irregularities in the operation of the apparatus during that period. The potential gradient, even though decidedly variable, was considered positive or negative, as the case might be, if it did not pass to the opposite potential during the period of at least an hour. Mean X audibility values were determined for the station under investigation. See Tables XII and XIII.

TABLE XII.

Tables Showing Comparison Between Potential Gradient of the Air and X Audibility.

Cases in which Potential Was Positive.

	May	June	July	August	September	Total
Similar departures from mean..	26	94	57	39	33	192
Opposite departures from mean.	59	109	53	49	56	273
When potential gradient was at mean value X audibility was low........................	28	73	36	64	20	185
When potential gradient was at mean value X audibility was high........................	18	37	13	32	27	114

Cases in which Potential Was Negative.

	May	June	July	August	September	Total
Similar departures from mean..	2	5	0	3	1	11
Opposite departures from mean.	2	4	3	1	4	11
When potential gradient was at mean value X audibility was low........................	0	0	0	0	1	11
When potential gradient was at mean value X audibility was high........................	0	0	0	0	1	1

TABLE XIII.

Cases in which Potential Gradient Fluctuated from Positive to Negative Values.

	May	June	July	August	September	Total
When X audibility was high...	6	15	22	5	0	26
When X audibility was low....	7	7	0	0	0	14

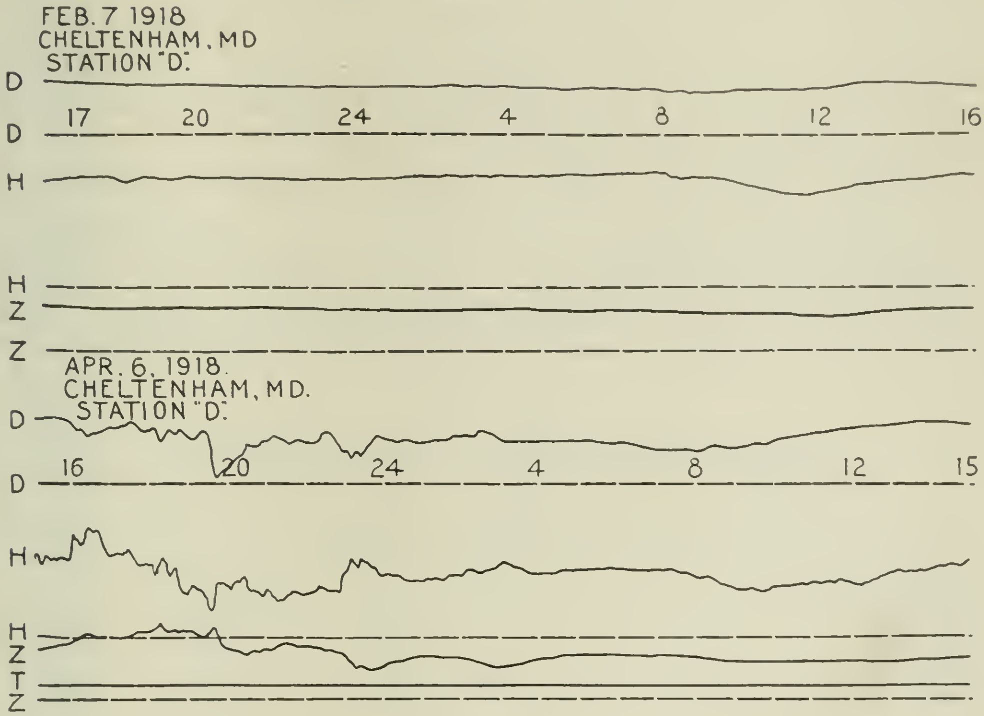
It will be noted that the greatest number of counts appear in the case of opposite departures, that is to say, when the potential gradient is high the X audibility appears to be low. This result is unexpected.

An examination of those cases in which the potential gradient was negative does not show any apparent agreement between X intensity and potential gradient.

In certain cases the potential gradient showed marked rapid fluctuations from positive to negative values. In a decided majority of such cases the X intensity was found to be high.

As a result of the preliminary investigation above outlined it was decided to secure and install suitable apparatus for photographically recording the potential gradient of the air in the immediate vicinity of a horizontal antenna, the potential of the earth beneath the antenna and the electrical disturbances in the antenna, simultaneously. This investigation was to have been carried out at the Signal Corps Field Laboratory near the City of Washington, and the equipment was practically ready for operation at the time the general Transatlantic investigation was discontinued. It is believed that an investigation, such as was projected, would yield valuable data bearing upon the cause of that part of extraneous disturbances which is of local origin.

Exhibit F.



VARIATIONS IN THE EARTH'S MAGNETIC ELEMENTS VERSUS X INTENSITY.

Passing from a consideration of meteorological elements and their possible relation to extraneous disturbances, it is desired to record the study made of certain other factors in connection with X intensity.

Owing to the fact that, in handling radio telegraph traffic, certain days occur when all receiving stations suffer more or less from what appears to be a general electrical disturbance in nature, thus indicating some general and possibly remote cause, it was decided to compare the variations in X intensity with the variations in the earth's magnetic elements.

Copies of magnetograms from the Magnetic Observatory at Cheltenham, Md., were furnished by the United States Coast and Geodetic Survey. These curves show the declination (D), the horizontal component (H), and the vertical component (Z), of the earth's magnetic field. Several sample magnetograms are shown as Exhibit F, one being typical of a magnetically calm day and the other a day subject to marked disturbances. In the curves used a movement above the base line corresponded to increasing West declination, increasing H, and increasing Z.

Marked departures from the mean X audibility values and mean values for D, H and Z were noted for six receiving stations, the stations at Fort Monroe and Ashland being considered as one station, and likewise the stations at Devens and Rockport. Table XIV shows the ratio of similar departures to opposite departures.

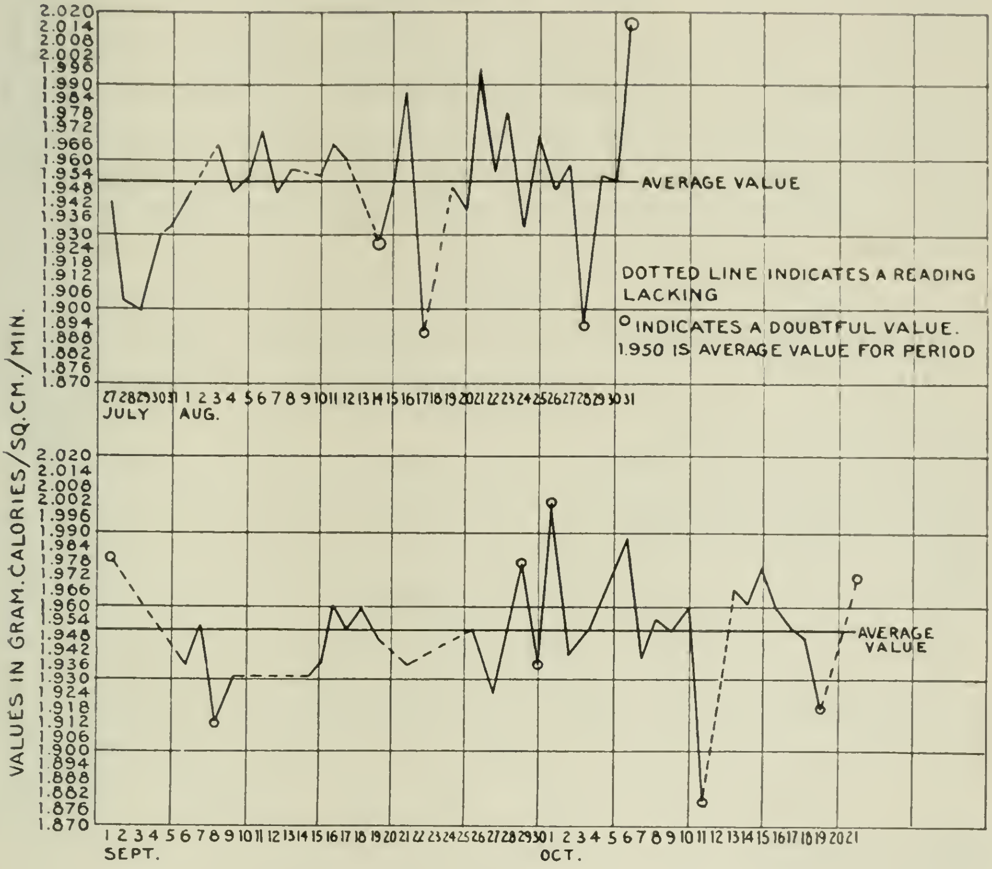
TABLE XIV.

Ratio of Similar Departures to Opposite Departures.

Station	D	H	Z
Virginia	1.76	2.36	1.77
Massachusetts	1.19	2.24	2.79
Screven	1.14	3.45	1.50
Princeton	4.86	2.44	3.83
Snelling	1.04	2.90	2.06
Brown	.87	1.44	1.84
Mean	1.81	2.47	2.29

It will be observed that, in the case of all stations, there were more similar than opposite departures. This is particularly true with respect to H and Z, in the case of H there being nearly two and a half times as many similar as opposite departures. Further, the H curve generally showed a drop near mid-day, the lower values occurring at or after noon in January and about 10 A.M. in June. At about the same time of day D showed a slight fall and a subsequent rise: Z also falls in value. These lower values of the magnetic elements which generally occur at or near midday coincide approximately with the diurnal minimum of X intensity, the latter being referred to in subsequent paragraphs. It would thus appear that a direct relation exists between the variations in the earth's magnetic elements and X intensity, and that extraneous electrical disturbances may be said to vary directly with the intensity of the horizontal and vertical components of the earth's field.

EXHIBIT G.



Solar constant values. Calama, Chile, July 27–October 22, 1918.

VARIATIONS IN THE SOLAR CONSTANT AND X INTENSITY.

Having found what appears to be a definite relation between X intensity and the variations in the earth's magnetic elements, the next natural step was to examine the variations in the solar constant.

The Astrophysical Observatory of the Smithsonian Institution furnished a table of values of the solar radiation constant, the data for which were obtained at Calama, Chile, covering a period from July 27 to October 23, 1918. A curve showing the variations in the solar constant for the above period was plotted from this data and is shown as Exhibit G. The mean value for the period was found to be 1.950 gram calories per square centimetre per minute. Two comparisons were made. In the first the grade of copy received at the receiving stations was used as a basis. On such days as decidedly poor or good copy was received the solar values were examined. In the second comparison X audibility values were taken as the basis, a mean weekly value of the X intensity being used. Those days during which the audibility remained above the mean weekly values were considered as having high X intensity, and those on which the audibility remained below the mean value were considered as having low X audibility values. On those days of decidedly high or low intensity the solar constant values were noted. See Tables XV and XVI.

TABLE XV.

Comparison Between Value of Solar Constant and X Audibility.

	Ashland	Ithaca	Princeton	Oberlin	Total
Similar departures from mean......	8	8	16	14	46
Opposite departures from mean....	60	16	17	21	114
When solar constant was at mean value X audibility was high.....	3	2	0	1	6
When solar constant was at mean value..........................	1	4	6	2	13

TABLE XVI.

Comparison Between Value of Solar Constant and X Audibility.

Solar Constant Values	Grade of Copy Received	
	Poor	Good
Mean..	8	3
Slightly above mean..........................	5	5
Very high....................................	3	1
Slightly below mean..........................	2	5
Very low.....................................	3	1

An examination of these tables discloses the fact that there also appears to be a relation between the value of the solar constant and X intensity, this being apparently more marked at certain stations than at others. It is also interesting to note in this connection that the X intensity appears to vary inversely as the value of the solar constant. Bauer has shown that there is a definite relation between the solar constant and the earth's magnetism. "In general, the effect of increased solar activity is to cause a decrease in the earth's intensity of magnetism, though there may also be at times a reverse effect." It will thus be seen that the radio data, while perhaps not conclusive, falls into line with what is known with respect to solar and magnetic relations. It is therefore quite probable that the general extraneous electrical disturbances, which are encountered in handling radio telegraphic traffic, are intimately associated, in the last analysis, with solar activity.

GENERAL OBSERVATIONS ON EXTRANEOUS DISTURBANCES.

An examination of the data collected at the several Transatlantic Receiving Stations shows that there is a diurnal variation in the X intensity which has a fairly well defined minimum for all stations at approximately 10 A.M., with a secondary minimum sometimes occurring at about 6.30 P.M. The maximum values occur between 10 P.M. and 4 A.M., the highest value commonly occurring about 3 A.M., with a secondary maximum shortly before midnight.

While there exists, as noted above, a more or less well-defined diurnal change common to all stations, it is true that frequent and radical changes in X intensity may occur at a given station which do not manifest themselves simultaneously at other stations. This is evident from a study of the data presented in Tables XVII, XVIII and XIX. In preparing these tables only abrupt departures of X intensity from mean values were considered. Instances when the X intensity remained at 8000 audibility for some time were not considered. The tables are self-explanatory.

The investigation was also extended to include an examination of those cases in which radical similar departures from the mean X audibility occurred at one station within a period of two hours prior to, or subsequently to, a similar occurrence at the other station. The results are embodied in Table XX.

The foregoing data lead to several important observations. From the first two tables of this group it is evident that in no case does the X audibility exhibit a simultaneous similar marked change at all six stations, or even at five of the stations, and shows only two similar departures at five stations within a period of two

TABLE XVII.

Agreement of Radical Changes in X Audibility at Same Hour.

Date	Number of days	Number of stations where changes in X intensity agree			
		2 stations	3 stations	4 stations	5 stations
February 1–March 15	42	46	16	3	0
March 15–May 23	68	43	17	5	0
May 23–August 1	70	58	9	0	0
Total	..	147	42	8	0

TABLE XVIII.

Agreement of Radical Changes in X Audibility Within Two Hours.

Date	Number of days	Number of stations where changes in X intensity agree			
		2 stations	3 stations	4 stations	5 stations
February 1–March 15	42	35	22	1	2
March 15–May 23	68	45	13	1	0
May 23–August 1	70	38	14	2	0
Total	..	118	49	4	2

TABLE XIX.

Opposite Radical Departures of X Audibility from Averages at Special Radio Station at Same Hour.

Date	Number of days	Number of stations where changes in X intensity is opposite			
		2 stations	3 stations 2 agree 1 opposite	4 stations 2 high 2 low	4 stations
February 1–March 15	42	15	10	0	1
March 15–May 23	68	18	4	2	1
May 23–August 1	70	19	6	0	0
Total	..	52	20	2	2

TABLE XX.

	February	March	April	May	June	July	Total
X audibility change earlier in Massachusetts than in Virginia	5	1	2	8	1	1	18
X audibility change earlier in Virginia than in Massachusetts	4	2	9	5	0	2	22

hours. This would appear to indicate that at least a portion of the extraneous electrical disturbances which give rise to interference and radio communications, are of comparatively local origin. It will be noted that there were 147 cases where the disturbed conditions at the two stations exhibited simultaneous radical changes, and 118 cases where the changes occurred within two hours. From this, it might be inferred that the disturbance which gives rise to X's moves. Since there were 52 cases of opposite simultaneous departures, it would also appear to be evident that at least a portion of the disturbance is not entirely local in origin. It may be of interest to note that it was found that radical changes occurred more frequently in the period preceding March 15 than later, and that the change in X audibility is somewhat more apt to occur earlier in Virginia than in Massachusetts, since in the copy made, the changes occurred 22 times in Virginia before they did in Massachusetts, as against 18 times in Massachusetts before the occurrence in Virginia.

In dealing with the results of extraneous interference, it is both interesting and significant to note that during the period covered by the operation of the Special Transatlantic Stations, it frequently occurred that an inland station would be able to secure portions of copy lost by all of the coastal stations. For example, the station at Ithaca and, at times, the one located in Ohio, would secure words or phrases which the coastal stations were unable to copy. Similar instances occurred with respect to Transpacific operation. At least on two occasions the Signal Corps Special Receiving Station, located at Fort Leavenworth, was able to read the Naval station at Pearl Harbor attempting to work the station at San Diego when the latter station, as indicated by service messages, was experiencing great difficulty in copying the former station.

While dealing with the question of general electrical disturbance, it is found interesting to note the frequency of electrical storms in different regions as shown by charts published in the *Monthly Weather Review* for July, 1915, as part of a paper by Mr. W. H. Alexander. At some period during the Transatlantic investigation, five receiving stations were located on or near the same 400-storm line, two near the same 300-line, two near the same 200-line (the Sault St. Marie station which was installed just as the observations were discontinued would also have been on the same 200-line) and one on the 100-line. As a result of the experience gained during the observations, it would appear to be true that so far as that part of the extraneous electrical disturbance which is of local origin, particularly that due to electrical storms, is concerned, the ten-year storm map may serve as a rough guide with reference to the possibility of X intensity in a given region. It had been planned to make a radio survey of the region covered by the states of Oregon and Washington, where, as shown on the storm map, only 25 thunder storms occurred during a period of ten years, and what is possibly more significant, no storm lines of high value pass near that region. The projected survey was not carried out owing to the discontinuance of the investigation as a whole.

In selecting sites in new regions to be investigated, a very interesting and important factor was encountered. In certain localities it was found that a change of less than a mile in the site of the station resulted, in a number of cases, in a decided modification in both the X intensity and strength of signals. The observation just referred to, and other considerations, led to the practice of carrying out preliminary radio surveys of a given region before a final site was determined on for a test station. For example, before deciding upon the location of the station at Van Buren, Maine, two preliminary surveys were made on the eastern half of the state. One survey included Houlton, Caribou, Van Buren, and Ft. Kent. During a late survey, simultaneous observations were made at Bar Harbor, Orono, Houlton, and Van Buren.

In carrying out this and other similar surveys, use was made of special portable receiving sets in conjunction with a single wire low horizontal antenna, the receiving sets having previously been compared at some given station. The results secured at the preliminary sites were then carefully compared with respect to X intensity and signal strength, the ratio of these two factors and also the actual copy secured serving as a basis of comparison. While referring to the matter of surveys, it may be stated that radio surveys similar to the above were carried out in the region of the Oberlin, Ann Arbor, and Madison stations. Such a survey was also made of the region about Sault St. Marie before establishing at that point. It is believed that such surveys are invaluable in a preliminary determination of optimum receiving centres.

SIGNAL STRENGTH.

Turning now to the question of the other variable in radio work, namely, changes in signal strength (audibility), it may be said that this phase of the general problem was given careful attention. In studying the variations in signal strength the traffic from the station at Lyons, France (YN), was taken as a basis.

An examination of the records showing the mean daily signal audibility of Lyons (LN) as noted at three of the receiving stations, indicates that the signals from a given station may show a comparatively high audibility value at one or more of the stations on a certain date and at the same time a low value at another station, and *vice versa.* It is also evident that the signals from a given transmitting station may have a high audibility value at a given receiving station on a certain date, while signals from some other station are comparatively weak at that particular time, and *vice versa.* It was also found that a given station might show a comparatively satisfactory signal audibility for a period of time of the order of a month or several months, while during some other period the signal audibility would be found to be low.

An effort was made to determine whether barometric conditions over the North Atlantic Ocean bore any possible relation to the variations in signals from the station at Lyons. Charts covering the month of March, 1918, were prepared for use in this investigation by the Weather Bureau and showed barometric areas across the North Atlantic, especially in the region of the great circle passing through New York and Rome, and near Lyons. The data available for the compilation of the charts above referred to were limited, owing to military conditions. The data showed that when a low barometric area in Midatlantic existed on the great circle referred to the signals at Devens had decidedly low values in seven cases and decidedly high values in two cases. At the Fort Monroe Station, under the above conditions, the signal audibility showed a decidedly low value in ten cases and high values in seven cases. The following table (XXI) shows a comparison between the audibility of the Lyons signals and the condition of the sky over the Atlantic on the great circle above indicated.

In the above connection it should be noted that during the period considered lows obtained across or above the particular great circle and highs below. At no time during the month was there a high off the North American coast or in the middle of the ocean over the circle. The only locality where high areas occurred was on the European coast. From an examination of the limited data available it would appear that a low pressure area on the great circle in Midatlantic tends to result in low signal audibility on the American Continent. There is also some evidence for the tentative conclusion that cloudiness over the Atlantic on the great circle results in low signal values at the receiving stations. Owing, however, to the limited amount of data available for this particular phase of the investigation, it would obviously be profitable to extend the study over a longer period under conditions favorable to the securing of more complete data.

TABLE XXI.

At Devens, Massachusetts	Low signal audibility	High signal audibility
(Sky condition)		
Blue sky	2 times	2 times
Partly cloudy	6 times	2 times
Cloudy	4 times	4 times
At Fort Monroe, Virginia	**Low signal audibility**	**High signal audibility**
(Sky condition)		
Blue sky	1 time	3 times
Partly cloudy	5 times	4 times
Cloudy	7 times	4 times

Charts were prepared setting forth the hours at which the signals from a given station (Lyons) have maximum and minimum values, respectively. These charts clearly indicated that the maximum and minimum values do not necessarily occur simultaneously at the several receiving stations. These charts also show that the maximum and minimum values at a given receiving station on a given day may obtain for a period of several hours; further, these maximum and minimum values do not occur at the same hour each day and appear to bear no definite relation to the time of sunrise, except possibly that the maxima are more apt to occur in the forenoon, prior to 10 A.M. This latter observation is evident from the data recorded subsequently to approximately August 1, at which time Lyons began to work a daily schedule which extended practically throughout 24 hours.

It is also desired to direct attention to a period of unusually high signal audibility during the latter part of March. The audibility values just referred to were more or less common to all the receiving stations, and applied to the signals from the stations at Rome, Carnarvon and Lyons. This phenomenon was also noted by the Navy Department. The writer is informed that the records of the Department of Research in Terrestrial Magnetism of the Carnegie Institution show that an abnormally high value of the electrical conductivity of the air occurred on March 21. This date falls within the period of abnormally high audibility values above referred to. This, of course, may be only a coincidence, and yet the occurrence naturally suggests the advisability of investigating the possible relation of the conductivity of the atmosphere to radio signal strength. In order to accomplish this satisfactorily it would be necessary to establish a chain of observatories between the transmitting and receiving stations in order to secure reasonably comprehensive data with reference to the conductivity of the air.

The experience gained during the Transatlantic investigation shows that a given receiving station does not necessarily functionate equally well in receiving from all transmitting stations. For example, the station at Fort Screven, Ga., was never able to secure satisfactory signals from Rome; the station at Oberlin, Ohio, was more or less unsuccessful in receiving the station at Nauen, Germany; and the station at Madison could not successfully secure copy from the station at Lyons.

Experience also leads to the conclusion that comparatively little energy from the European stations, particularly from the station at Lyons, passes beyond the Great Lakes. The station was installed at Sault St. Marie, Mich., to further investigate this point, but the termination of the Transatlantic investigation prevented the carrying out of this part of the program. However, the results of a preliminary radio survey made in the region of Sault St. Marie tend to show the latter site would prove to be a fairly satisfactory inland receiving centre.

Since the signal strength of all European stations as received at the Signal Corps station at Ithaca, N. Y., was always comparatively high, and since the storm map before referred to shows fewer electrical storms in the northern part of New York State in the region of the St. Lawrence River than at Ithaca, it was planned to investigate the region of the St. Lawrence River.

The closing of the experimental work also prevented the carrying out of this survey. In view of the facts just stated, and also because of the fact that the great circle from Lyons passes approximately down the St. Lawrence River Valley, it is believed that a radio survey of that region in New York should be made.

In general it may be said that the stations at Rockport, Mass., and Princeton, N. J., experienced the strongest signals, with the Ithaca station ranking next. The Virginia and Maine stations showed signal values of the same order of magnitude, but of decidedly lower value than the stations above mentioned. The signal strength at Oberlin was of the same order as that which obtained at the Maine and Virginia stations. As previously stated various steps were taken to check the above indicated result. Certain additional checks were about to be made just as the work was terminated. If the data extending over nearly a year are at all indicative of actual conditions, it would appear that the geographical distance of the receiving station from the transmitting station is not by any means the only important factor in predetermining received signal strength.

INVESTIGATION OF ANTI-X DEVICES AND AGENCIES.

At the same time that data bearing on X's and signal strength were being collected and studied, an effort was also made to investigate various suggested and original anti-X devices and agencies. In order to carry out this feature of the work most effectively a field laboratory was installed in Maryland just outside of the District, west of Washington. The equipment was sheltered in a portable house similar to those used at several of the receiving stations. The site of the laboratory was in an open field, the temporary use of which was donated by patriotic citizens of Washington, thus affording excellent opportunity for thoroughly testing various antenna systems and other anti-X devices.

Starting with the well-known fact that a low horizontal antenna is less subject to extraneous electrical disturbances than one of the vertical type, a number of antenna arrangements and other devices were investigated with respect to their anti-X properties. While X's and signal audibility measurements were made in each case, the final tests as to the effectiveness of any given device or agency was whether an operator could actually make better copy with the apparatus under test than with the standard low horizontal antenna.

Previously to the experiments at the Field Laboratory above referred to, helices, 15 ft. square (see Fig. 3), were constructed at Camp Devens, Ft. Brown, Ft. Screven, and Ft. Monroe stations, and a 12 ft. helix at the Oberlin station. The winding of the 15-foot helices consisted of 40 turns of stranded copper wire, spaced ¼ inch between centres. The 12-foot helix had 45 turns. The helices at Camp Devens, Ft. Brown, and Oberlin were housed. Tests were carried out to determine the relative effectiveness of these helices when compared with the horizontal antennas used at the stations. The evidence showed conclusively that the helices did not possess any advantage over the horizontal antennas. The ratio was not improved and at times the signals on the helices were prohibitively weak.

Both audio and radio balancing between two helices at right angles were tried in an effort to neutralize the X effects, but without success. Simultaneous photographic records of X impulses received on two helices placed at right angles to one another and in a vertical plane appear to show that the extraneous disturbances do not occur simultaneously at two mutually perpendicular planes. The amplitude of the impulses recorded is not significant. In making these records the receiving and recording apparatus were interchanged from time to time in order, as far as possible, to eliminate experimental errors. In making these records the helices had a common vertical axis and it is possible that electrostatic coupling between the two helices existed. In view of this possibility, these tests should be repeated with the helices placed far enough apart to reduce the coupling to a negligible quantity.

The screening of a horizontal antenna was also investigated. A horizontal thousand-foot (305 metres) single-wire antenna was placed at a mean distance of approximately 3 feet (0.9 metres) above the ground and enclosed in a screening system composed of closed loops of copper wire 18 inches (45.8 cm.) in diameter, the plane of the loops being vertical and spaced at a distance of 20 inches (50.8 cm.). These loops were connected by high resistance wire and the screening system was grounded at several points throughout its length through 2500 ohm resistance units. Repeated tests showed that such a screening system possessed no advantages over an unscreened system.

It has been suggested that a mechanical covering for the antenna system might prevent the deposition of local electrical charges on the wire of the antenna, with the attendant electrical disturbance. In this connection, it may be noted that the large helices, referred to above, were constructed of insulated wire, and several of the helices were used within a building. No noticeable difference was observed, so far as X's are concerned, between the behavior of the helices operated in the open or enclosed. Further tests along this line were carried out at the Field Laboratory. Careful measurements were made on two horizontal antennas, the wire of one of which was covered with a light insulating material having a comparatively low specific inductive capacity, and an antenna constructed of bare wire, but otherwise identical. No difference in the functioning of these two antennas could be detected.

It was thought that possibly an antenna having concentrated capacity might be less subject to extraneous electrical impulses than one composed of long wire. An antenna consisting of 600 square feet (55.74 square metres) of copper window screen, and supported at various heights above the earth's surface up to 12 feet (3.7 metres), was compared with a 1000-feet (305 metres) horizontal antenna consisting of 2 wires. The signal strength on the copper screen antenna was prohibitively low, and the ratio showed no improvement over the usual horizontal antenna.

Another anti-X possibility investigated consisted of a vertical subterranean antenna. At Dumfries, Va., about thirty miles (48.3 Km.) south of the City of Washington, is located the Cabin Branch Mine, which produces iron and copper pyrites. There is in this mine a vertical shaft 1000 feet (305 metres) deep. A series of preliminary comparative tests was made at this mine in April, and a more complete series of experiments was carried out in the latter part of July. A vertical insulated wire, approximately 1000 feet long, was suspended in this shaft, and a receiving set connected to the upper end, various earth connections being tried, such as steam and water pipes in contact with moist earth.

For a basis of comparison, an antenna consisting of a single horizontal wire, 1000 feet long, was extended over the ground to the southwest from the mine entrance, and supported on trees high enough above the earth to clear the surface vegetation; the maximum height of this wire did not exceed 4 feet (1.2 metres).

A careful comparison was made between the X intensity and signal strength when using the horizontal and the pendant antennas. Signals from the station at Lyons (YN), France, and Carnarvon (CV or PI), Wales, were easily readable on the pendant antenna. The signal strength when using the pendant antenna was always less than when using the horizontal wire inside the mine. Extraneous disturbances were noted when using the pendant antenna. The ratio, however, between X's and signals was in all cases found to be greater (less favorable) when using the pendant antenna than when employing the horizontal wire.

The receiving set was also connected to the lower end of the pendant wire, earth connection being made to piping at the bottom of the mine. Under the above conditions signals from Lyons (YN), France, were heard loud enough to be identified, but were not loud enough to make copy possible, and the ratio was unfavorable. Signals from several high power American stations were heard with comparatively high audibilities when the receiving apparatus was connected to either the upper or lower end of the pendant wire.

Following is a table giving the data secured during the tests made in July:

TABLE XXII.

Day	Hour	Antenna	Station	Audibility		Signal Static
				Static	Station	Ratio
7/28	8 : 55 A. M.	Outside	Y. N.	140	40	3.5
7/28	8 : 55 A. M.	Top mine	(Y. N.) stopped	170	..	....
7/28	9 : 20 A. M.	Outside	P. I.	200	80	2.5
7/28	9 : 20 A. M.	Top mine	P. I.	170	40	4.25
7/28	9 : 25 A. M.	Top mine	Y. N.	200	18	11.1
7/28	9 : 25 A. M.	Outside	Y. N.	170	50	3.4
7/28	12 : 00 M.	Bottom mine	(15000 M.)	40 (No stations)		
7/28	3 : 00 P. M.	Outside	P. O. Z.	8000+	250	32
7/28	3 : 00 P. M.	Mine	P. O. Z. not heard	8000+	...	....
7/28	10 : 00 P. M.	Outside	....	250	....	....
7/28	10 : 00 P. M.	Mine	....	300	....	....
7/29	8 : 00 A. M.	Outside	Y. N.	100	35	2.8
7/29	8 : 00 A. M.	Top mine	Y. N.	60	12	5
7/29	8 : 45 A. M.	Bottom mine	15000 M.	26 (No station)		
7/29	8 : 45 A. M.	Bottom mine	W. G. G.	26	8000 −	307
7/29	8 : 45 A. M.	Bottom mine	W. I. I.	(Standing by)		
7/29	9 : 00 A. M.	Bottom mine	Y. N.	26	5	5.2
7/29	10 : 55 A. M.	Bottom mine	Y. N.	50	6	8.3

The tests with subterranean vertical antenna show that a receiving system of this type does not possess any advantages with respect to the elimination of extraneous disturbances over low horizontal type of antenna. A pendant antenna, however, might possess certain more or less obvious military values. It is believed these subterranean tests should be extended to include experiments in coal and other mines, setting both vertical antenna and also horizontal wires at different levels beneath the surface of the earth.

RADIO TRANSLATOR.

The most promising device for the elimination of extraneous disturbances, including interference from other stations which we have investigated, is a device designed by this Branch, a working model having been constructed in the Signal Corps Field Laboratory. Briefly, this device consists of a tuned reed associated with an electromagnetic system, and an external acoustic resonating chamber. Drawings showing several different ways of assembling the parts are shown as Exhibit N.

The telephone receiver commonly employed in connection with radio reception is incorrectly designed for use in radio work. The telephone receiver was originally constructed to reproduce the voice with its many overtones, hence the diaphragm is highly damped and has a comparatively flat resonance curve. The result of such a construction is that X and other extraneous impulses excite the diaphragm, as well as the signals themselves. The signal impulses from a radio receiving set closely approximate a monotone; that is, the signal tone is comparatively free from overtones or upper partials. Quality or timbre therefore need not be considered in arranging to translate these electrical impulses into audible sounds. It therefore becomes possible to design a translating device for use in radio work which will be highly selective with respect to signal tones and which will respond but feebly to impulses out of resonance with the vibrating member.

Proceeding along the lines just indicated, the device referred to in the second paragraph above has been developed. By the use of a comparatively stiff steel reed, R, of the proper coefficient of elasticity, and fastened at one end only, the so-called "musical effect" of the X's, commonly present in other similar devices, is very much reduced. The proper mechanical relation of the resonant chamber, C, to the reed is important. Energy from the resonant chamber is conveyed to the ears of the operator by means of short rubber tubes similar to those of a stethoscope. The device is exceedingly simple and robust. It is preferable to enclose the resonant chamber and the electromagnetic parts in such a manner as to prevent extraneous noises and air-currents from acting upon

EXHIBIT N.

FIG. 1.

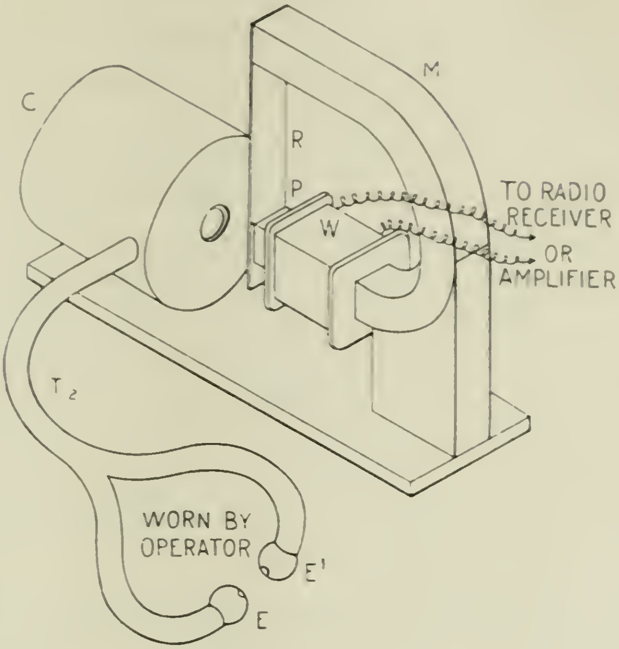


FIG. 2.

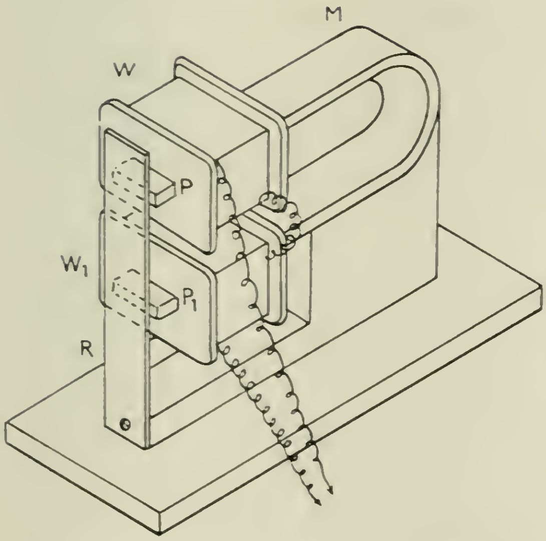
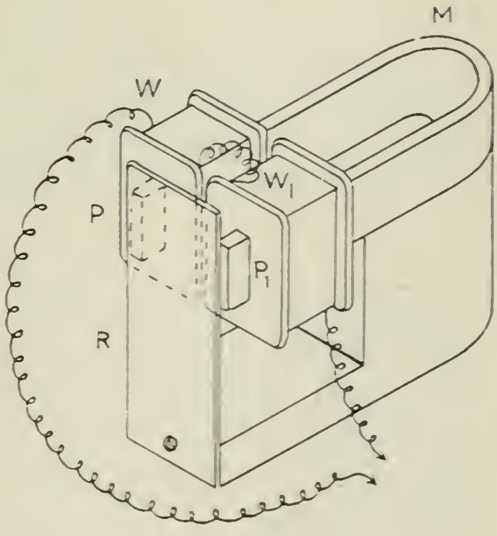


FIG 3.



Radio translator.

the resonant chamber. The efficiency of this device, which might be called a radio translator, is not as high as the best receivers used for radio purposes, but repeated tests show that the ratio of the X's to signals is materially improved by the use of this apparatus, and high when using the radio translator, in connection with two steps amplification, for comfortable reading. The use of the new device makes it possible to reduce the ratio in practically all cases at least to unity.

Aside, however, from the possible utility of this device in connection with the reduction of the effects of vagrant extraneous disturbances, the apparatus should prove to be of considerable utility in preventing interference from nearby high power continuous wave or spark stations. Its performance in this respect has been very satisfactory. Owing to the fact that the device consists essentially of a double filter, it has been found by actual tests that wave lengths differing by at least 1 per cent. can be completely shut out. It has also been found that this receiver when used for the reception of spark signals smoothes out the spark tone into a clear musical note.

Owing to the fact that the final design of the radio translator was not completed until about November 1, it was not possible to give the device a trial at the several receiving stations, but practical tests made at the Field Laboratory extending over a period of a number of weeks have shown that the invention of this apparatus marks a distinct advance in the means designed to overcome the interference in radio communication. Steps are being taken by the Chief Signal Officer to secure legal protection for the use of the radio translator by the Government.

RADIO AUDIOMETER.

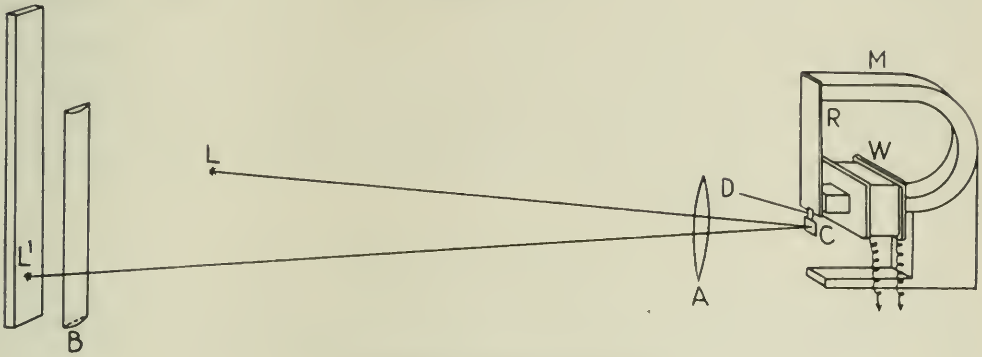
Another piece of apparatus developed at the Field Laboratory, which, though not an anti-X device, is so closely related to this and similar future investigations that it will be described here.

All who have attempted to deal with the measurement of radio signal strength appreciate the desirability of an improved method of making such measurements. An effort has accordingly been made to devise some device or combination of apparatus which might give results that are more nearly quantitative than those obtainable by the shunted telephone method.

Reference has just been made to a piece of apparatus designed by the Transatlantic Branch to be utilized for the purpose of eliminating extraneous disturbances of various types. Using the electromagnetic system of the radio translator basis, a device was designed which gives promise of being a satisfactory quantitative method of measuring the intensity of radio signals and X intensity.

The drawing listed as Exhibit O shows the construction of the device. The electromagnetic system W actually used was that taken from a P-11 W E telephone receiver. The steel reed R was a portion of an artist's spatula, and should, in practice, be just stiff enough to prevent it being drawn to the pole pieces of the electromagnets when adjusted a distance from the same giving maximum sensitiveness. The length of the reed used depends upon the pitch of the beat tone desired.

EXHIBIT O.



Radio photographic recorder.

If a tiny mirror, C, of the order of a square millimetre in area, be fastened to the free end of the metal reed, R, by means of an exceedingly light and short piece of very flexible material, D, such as celluloid or collodion, and the reed is caused to vibrate, the mirror will tend to rotate about the axis located in the thin strip to which the mirror is fastened.[2] By making the strip which supports the mirror very short a beam of light reflected from the mirror to a scale 70 centimetres away will be moved through a distance equal to 2500 times the amplitude of the metal reed itself. Referring to the drawing, L is a suitable source of light, A and B lenses arranged to give a well-defined image of the source L at the conjugate focal point L, this image being received on a suitable scale or sensitive photographic paper. Signals having an audibility of 15 will give a deflection of 2 millimetres on the scale. A deflection of this magnitude is ample for photographic recording purposes and may readily be increased, by amplifying the signals or using a greater scale distance. For quantitative measurements the deflection may be read directly on the scale or by means of a second optical system. The essential parts of the apparatus are exceedingly simple and the device is very sensitive, having a higher sensibility and being decidedly more rugged than the similar apparatus made by the General Electric Company. X impulses affect the system, giving sufficiently marked deflections, for quantitative measurements.

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[2] NOTE.—The Officer-in-Charge is indebted to Doctor Edwards, formerly of Bureau of Standards, for the suggestion of this means of optical multiplication.

Owing to the fact that the device was not developed until about December 1, samples could not be constructed and used for making quantitative measurements at the special receiving stations. However, the results secured in tests made at the Field Laboratory on Transatlantic signals indicate that the device gives promise of being a more satisfactory means of measuring signal and X audibility than the shunted telephone method. Steps are also being taken to protect the Government in use of this apparatus as a recording device.

UNCOMPLETED WORK.

The termination of the Transatlantic investigation prevented the completion of the following aspects of the work:

(*a*) The securing of data at Sault St. Marie, Mich., which was to have completed the radio survey of the Great Lakes Region.

(*b*) The investigation of the region adjoining the St. Lawrence River Valley in northern New York State, and also the Pacific Coast Region.

(*c*) The final checking of relative signal audibility values at the various stations by means of new and improved apparatus.

(*d*) The carrying out of a study of the simultaneous occurrences of X impulses in three mutually perpendicular planes.

(*e*) The securing of simultaneous photographic records of X impulses at a number of widely separated points, with a view to determining what part of such impulses are of local origin and what part is general in character.

(*f*) The study of the simultaneous potential of air in the immediate vicinity of an antenna, the earth beneath the antenna and the X impulses in the antenna, by means of photographic recording devices.

(*g*) The investigation of the functioning of both vertical and horizontal subterranean antennas.

GENERAL SUMMARY.

The extraneous electrical disturbances (X's) encountered in radio communication are undoubtedly composite in character, a part being more or less of local origin and a part having a remote genesis. The evidence appears to indicate that the local X's probably depend upon the combined effect of several meteorological factors, the velocity of the wind and the temperature of the air being important considerations, X intensity varying inversely as the factors just named.

A marked agreement was found to exist between relative humidity and the intensity of X's. Either the latter is a function of the former or there exists a common controlling factor.

Marked local differences in the X intensity undoubtedly exist, differences in station sites of the order of a mile resulting in decided differences in X intensity, and sometimes in signal strength.

Ten-year storm charts are found to serve as a rough guide as to the local X intensity which will be encountered in given regions.

That part of the electrical disturbances which is of a general nature probably has its origin in solar activity, it having been found that variations in X intensity correspond directly with changes in the earth's magnetic elements, particularly H, and there being also some evidence for the conclusion that X intensity varies inversely as the solar radiation constant.

There exists a diurnal variation in X intensity for all stations which has a fairly well defined minimum occurring at 10 A.M. The maximum values occur between 10 P.M. and 4 A.M., most frequently at 3 A.M.

A given receiving centre will not functionate equally well with respect to reception from different transmitting stations.

Maximum and minimum values of signal strength from a given transmitting station do not always occur simultaneously at different receiving stations.

A receiving station's effectiveness may vary from season to season and even from month to month, this being particularly true of inland stations.

A comparatively small amount of energy from the European stations, particularly Lyons (YN), passes beyond the region of the Great Lakes.

Within certain limits, geographical distances from the transmitting station are of secondary importance in determining the quantity of radiated energy which reaches a given receiving station.

Local as well as general radio survey should be made before definitely deciding upon permanent sites for receiving centres.

Transatlantic radio traffic can be handled at practically any point on the Atlantic Coast from Ft. Monroe northward, the ratio between X's and signals, however, was found to be more satisfactory at certain points at or near the coast than at others.

The immediate vicinity of Washington is probably as satisfactory for a receiving centre as any point near the Atlantic Coast south of Massachusetts.

The northeastern section of Maine is believed to be the most satisfactory point for Transatlantic reception.

Inland stations frequently secure portions of copy missed by all coastal stations.

Because of the fact that violent local electrical disturbances may occur, and because maximum and minimum values of signal strength do not necessarily occur simultaneously at all places, it is desirable to have several receiving centres in operation at the same time. It is believed that uninterrupted service can be maintained by establishing three such receiving centres, one of these centres to be located just outside the City of Washington, one in northeastern Maine, and one in northern New York State in the vicinity of the St. Lawrence River. The copy secured at the Washington station should serve as a basis, missing parts being supplied from the other receiving centres. The land line tolls would thus be reduced to a minimum.

The Signal Corps Transatlantic receiving stations could have handled the entire incoming traffic on and after August 1, 1918.

A device has been designed which reduces the X-signal ratio, and also eliminates interference from other stations if the wave length differs by one per cent. This device also changes the tone of a spark station to a pure musical note.

A simple quantitative method of high sensitiveness for measuring X intensity and signal strength has been developed. This apparatus may be utilized for the purpose of securing photographic records of radiograms.

In conclusion it is desired to record that a number of private individuals, educational institutions, and other organizations rendered valuable assistance during the course of the Transatlantic investigation by the loan of the use of land, buildings, and special apparatus.

WASHINGTON, D. C.,
December 31, 1918.

Aerial Photographic Mapping. M. A. KINNEY, JR. (*Flying*, vol. viii, No. 3, p. 250, April, 1919.)—No development brought about in the heat of intense war effort has greater peace time significance than that of aerial photography; aerial photography has opened an entirely new field of endeavor. Whereas the ordinary map surveyor would have to make his calculations on a yearly basis, the aerial photographic surveyor estimates from the standpoint of hours. By aerial photography, a map just as accurate as that produced by the surveyor, and far more comprehensive, can be made available within forty-eight hours after the flight to take the exposures.

When the armistice was signed, a number of automatic and semi-automatic cameras had been produced, ranging in size from the 4 x 5 camera with 8.5 inches focal length to the enormous cameras of 50 inch focal length and 8 x 10 plates. One of the most ingenious of these cameras is the Eastman K-1. This camera is entirely automatic in its action. It is set on the floor of the fuselage and operated by a controlled wind turbine. Roll film is used, and 100 pictures 8 inches by 10 inches in size can be made without reloading. The use of film of such large size presented a very great problem because of vibration. The difficulty was overcome by providing a vacuum suction which accurately holds the film in the recording plane without liability of static. This K-1 camera can in one continuous trip at an altitude of 10,000 feet take sufficient exposures to cover an area of some 200 square miles.

Photographic mapping can be accomplished by flying at a height of 10,000 feet using the K-1 automatic camera which will record approximately two square miles of area at the height named at each exposure. The photographs gathered on a mapping trip can be pieced together in an accurate mosaic by a method of triangulation. The photographic map on completion may be traced and interpreted into the usual form of topographical map. The work of developing and printing, piecing the photograph in mosaics, and tracing can be accomplished in a remarkably short time.

The Geophone. ANON. (*Communication, U. S. Bureau of Mines,* March 27, 1919.)—The geophone, a listening instrument invented by the French during the war to detect enemy sapping and underground mining operations and for the location of enemy artillery, is now being used by the Bureau of Mines as a possible aid in locating miners who have been entombed after a disaster. The instrument was developed by United States engineers during the war and is now used by the bureau according to plans drawn by these engineers. Alan Leighton, assistant chemist of the bureau, who now has charge of these investigations for the bureau, has given the following statement of general information regarding the geophone:

The instrument, though small, is essentially a seismograph, since it operates on the same principle as the ponderous apparatus with which earthquake tremors are recorded. It consists of an iron ring about three and a half inches in diameter within which is suspended a lead disc fastened by a single bolt concentrically to two mica discs, one of which covers the top and the other the bottom of the ring. Two brass cap-pieces cover the discs, the top one having an opening in its centre to which is attached a rubber tube leading to a stethoscopic ear-piece. These cap-pieces are fastened with bolts to the iron ring and serve to hold the mica discs in place. Essentially the apparatus is merely a lead weight suspended between two mica discs cutting across a small air-tight box. If the instrument is placed on the ground and any one is pounding or digging in the vicinity, energy is transmitted as wave-motion to the earth, and the earth-waves shake the geophone case. The lead weight, because of its mass and elastic suspension between the mica discs, remains comparatively motionless. There is thus produced a relative motion between the instrument case and the lead weight. The result is that a compression and rarefaction of the air in the instrument takes place. Since the rubber tube leading to the ear-piece is connected with this space in the geophone, this compression and rarefaction is carried to the ear-drums.

When two instruments are used, it has been found that the sound is apparently louder from the instrument nearer the source of the sound. By moving the instrument properly, a point can be found where the sound will be of the same apparent intensity in both ears. The direction of the sound is then on a perpendicular to the line joining the centres of the two instruments either in front of or behind the observer; further observation will show which side. Direction is quite accurately determined in this way. The sound is not actually louder in one ear than in the other, but the ear is capable of distinguishing the difference in time at which the sound arrives in the two instruments. Since this is the case, persons who are slightly deaf in one ear are said to still be able to determine direction with the instrument.

THE VAPOR TENSIONS OF THE METALS.*

BY

J. W. RICHARDS,

Professor of Metallurgy, Lehigh University.
Secretary of the American Electrochemical Society.
Member of the Institute.

It has been known for centuries that mercury could be boiled under atmospheric pressure, and it has been known for a long time that some other metals are volatile at high temperatures. We can at once state the general conclusion that all metals are volatile, or possess characteristic maximum vapor tensions at any given temperature.

Volatility, or exertion of vapor tension, is generally thought of in connection with liquids, and we speak of their normal boiling points as the temperature at which their vapor can exert 1 atmosphere pressure (760 mm. of mercury column). With many metals this single datum is the only one known; with a few, *e.g.*, mercury, cadmium, zinc, sodium, lead, thallium, bismuth, tin, silver and copper, several or many similar data have been determined, enabling us to plot to a greater or less extent their vapor tension curves.

Solids, however, can exert vapor tension, and the vapor tension of the solid at the melting point is the same as that of the liquid. The two curves, however, are not prolongations of each other; there is a cusp or bend in the curve at the melting point, the vapor tension of the solid being always *less* than the extrapolation of the curve for the liquid below the melting point. This behavior we know to be true of all materials (elements or compounds) whose vapor tensions in the solid and liquid states, below and above their melting points, have been determined, such as sulfur, iodine, bromine, water, and many inorganic and organic compounds.

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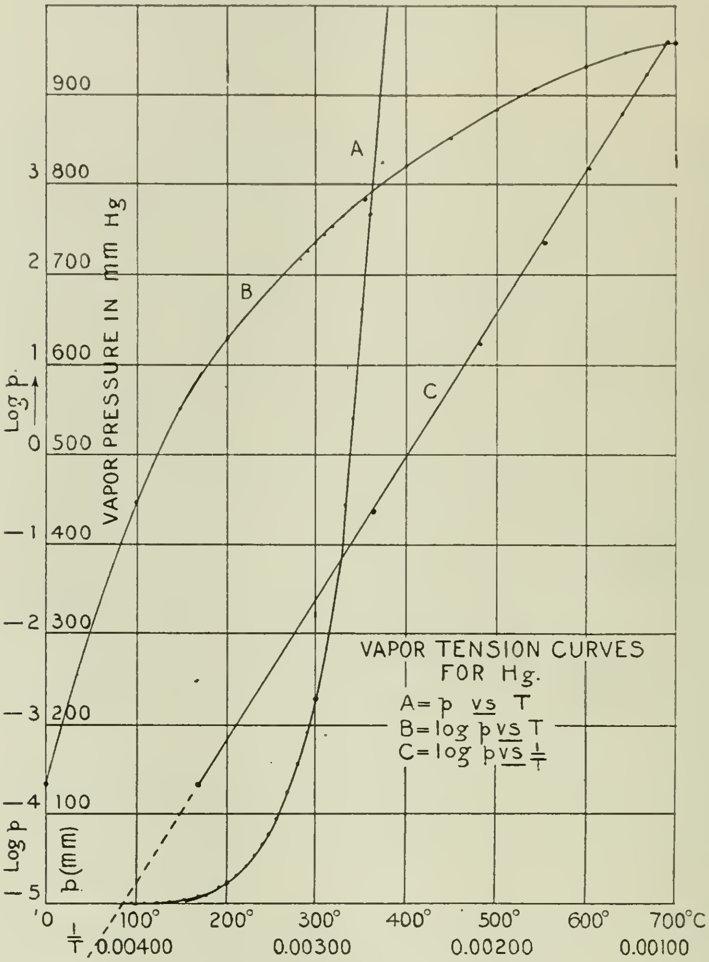
* Presented at a meeting of the Section of Physics and Chemistry held Tuesday, December 10, 1918.

VAPOR TENSION CURVES.

(A) Vapor Tension Plotted Against Temperature.

This is the simplest and most natural chart to make. It means simply charting the observed maximum vapor tensions against determined temperatures. Figure 1, line *A*, shows this for mercury. It will be noted that the curve is very flat at low temperatures and very steep at high temperatures. Such curves are difficult to draw, also difficult to interpolate accurately and almost impossible to extrapolate beyond observation points with any degree of probability. They are serviceable only within the limits covered by the experimental data, and even then are not very manageable. They cannot be expressed by any simple or convenient mathematical formula, although numerous attempts have been made to do it.

FIG. 1.



One valuable general deduction, however, has been made from a study of these curves, by Ramsay and Shields, *viz.*, that a nearly constant numerical relation subsists, for any two given elements or compounds, between the *absolute* temperatures at which they have the same vapor tension. Expressing this in mathematical language, if two substances A and B have the same tension p at T_A and T_B, and the tension p' at T'_A and T'_B, then

$$\frac{T_A}{T_B} = \frac{T'_A}{T'_B}$$

This relation is not exactly accurate, but approximately so. For instance, if A is mercury and B water, the value of the ratio is

$p =$ 34.4 mm. Hg. $T_A/T_B = 1.63$
$p =$ 157.2 mm. Hg. $T_A/T_B = 1.66$
$p =$ 761. mm. Hg. $T_A/T_B = 1.69$
$p =$ 2905. mm. Hg. $T_A/T_B = 1.74$

If chemically like substances are compared, however, the rule seems to hold closer. It follows from the above relation, mathematically, that

$$\frac{T_A}{T'_A} = \frac{T_B}{T'_B}$$

which expresses the fact that the ratio of the absolute temperatures at which a given substance has the pressures p and p' is the same as the ratio of the absolute temperatures at which another substance has the same pressures p and p'. If the relation first given is true the other must be true, and *vice versa*. Nernst gives such a comparison for five methyl salts, in which the ratio was 1.115 to 1.113, and ten ethyl salts, in which it varied between 1.117 and 1.111. It therefore appears likely that when metals are similarly compared, a like uniformity of ratio may be found, reliable enough to serve as a guide towards a first approximation. Mercury, in fact, gives the ratio 1.117 for the same pressures used comparing the methyl and ethyl salts. We therefore feel considerable confidence in applying the same principle when comparing one metal with another metal.

It will be shown in the next section that the vapor tensions of most of the metals can be fairly accurately represented by the formula

$$\log p = -\frac{A}{T} + B.$$

For a second metal we would have

$$\log p = -\frac{A'}{T} + B'$$

The above discussed relations are accurately true if the two metals have the same values of B, that is, if $B = B'$. If B is not equal to B', the above relations will not be constant; conversely, if the above discussed relations are constant, then the B's are all alike. This is strikingly true of the esters discussed by Nernst; it is only approximately true for water and mercury; it is probably nearly true for comparisons of the metals with each other.

(*B*) *Logarithm of Pressure Plotted Against Temperature.*

The form of the curve showing variation of vapor tension against temperature suggests investigating the variation of the logarithm of pressure against temperature, because of the asymptotic approach of the plain pressure curve towards zero at low temperatures and towards the vertical at high temperatures. In fact, an arithmetical analysis of the pressure curve confirms this by showing practically equal percentage (geometric) increases of the tensions for equal arithmetic increases of temperature. On plotting *log. p* for mercury against temperatures, the curve marked *B* in Fig. 1 is obtained. This is a slightly convex curve, with nearly equal curvature throughout, and therefore much better adapted for interpolation and extrapolation. These curves were used for some time, for plotting the vapor tensions of the metals, until a still more satisfactory relation was found.

(*C*) *Logarithm of Pressure Plotted Against Reciprocal of Temperature.*

A further study of the subject of pressures of liquids other than metals showed that when the logarithms of pressures were plotted against the reciprocals of the absolute temperatures, curves were obtained, with but slight curvature, approximating straight lines (see Curve C, Fig. 1). This is true of all such liquids and solids whose vapor tensions have been accurately determined. The curves are not straight lines, but only approximately so. A straight line relation would require $\log. p. = -\frac{A}{T} + B$ and this does not accurately fit the tabulated values; but the formula of

Nernst ($log.\ p = \frac{A}{T} + 1.75\ log.\ T - CT + D$), with three constants instead of two, correlates the observed pressures and temperatures satisfactorily.

The vapor tension data for the metals, with the single exception of mercury, are not accurately known, and we may say of these experimental data that the formula $log.\ p = -\frac{A}{T} + B$ (wherein A and B are constants, and T the absolute temperature) fits them in general within the experimental errors of the determinations. In short, while a Nernst formula with three constants may be constructed for mercury, the simpler straight line formula is all that we are justified in constructing for the other metals. This simplifies very much the discussion of the vapor tensions of the metals, and enables us to make generalizations from very scanty data.

DISCUSSION OF THE STRAIGHT-LINE EQUATION.

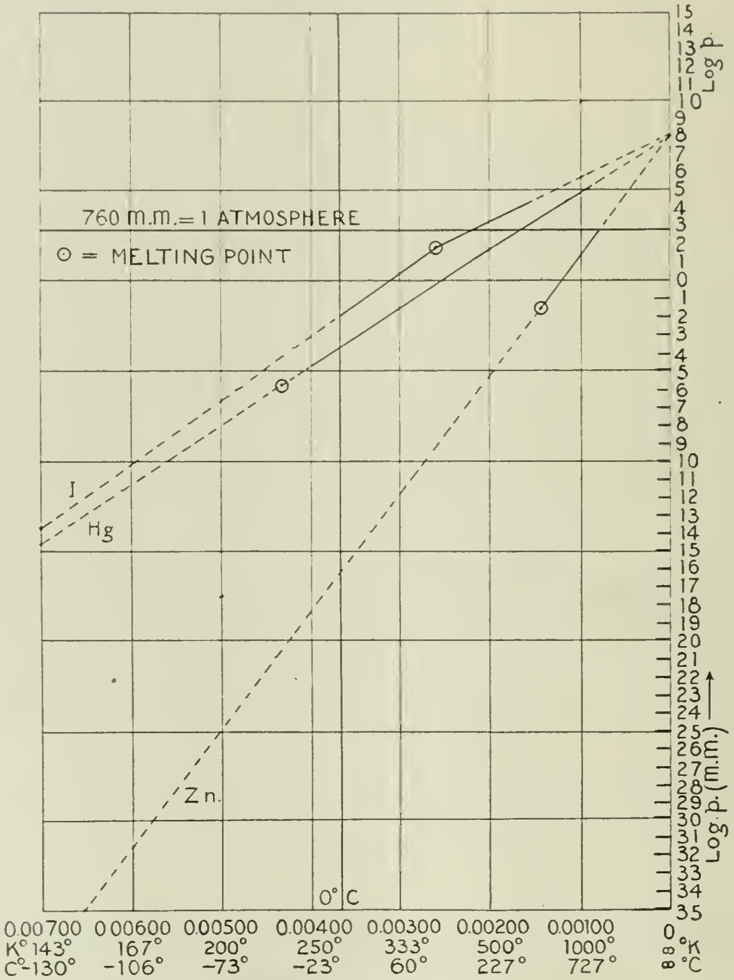
Plotting as accurately as we can the logarithms of the known vapor tensions of the metals against the reciprocals of the absolute temperatures, we obtain practically straight lines in all cases, within the experimental errors, as shown for iodine, mercury and zinc in Fig. 2. The right hand vertical line, representing $\frac{1}{T} = O$, really stands for infinite temperature, while absolute zero, $T = O$, would lie at an infinite distance to the left. In all cases, the vapor tension line, if prolonged beyond the observations, is seen to cut the right hand vertical, $T = \infty$, at a finite distance, which represents the value B in the straight-line equation. This, if exactly true, would indicate an absolute maximum pressure ($log.\ p_{max} = B$), which the substance could not exceed even with $T = \infty$. This is an interesting speculation, pointing to the conception of an absolute maximum of vapor pressure, the antithesis of the absolute zero of temperature.

Another interesting generalization is that for the different metals the values of B appear to be approximately alike. Where we have sufficient data to draw the line (at least two observations of tensions at two different temperatures) the indicated values of B appear to be as follows:

Sodium	6.85
Copper	8.75
Zinc	8.17

Arsenic	8.65
Selenium	8.10
Silver	7.90
Cadmium	8.74
Mercury	7.73
Lead	8.00
Bismuth	7.45
Average	8.03

FIG. 2.



According to this observation, we may as a first approximation to a vapor tension curve write

$$\log. p = -\frac{A}{T} + 8.00$$

and if we have only one determination of vapor tension, at some temperature, we can determine A. If we have T for $p = 760$ mm. (1 atmosphere), as is often the case, then $A = 5.22\ T$. This is frankly an approximate formula, since B is not properly a definite constant, but it is quite satisfactory to get a working formula which is approximately true, when only one value for the vapor tension is known.

The thermodynamics of this straight-line formula is interesting. The Clapeyron-Clausius equation gives the relation

$$L = RT^2 \frac{dp}{dT}$$

where L is the molecular latent heat of vaporization, T the absolute temperature, and R the gas constant, in calories.

Differentiating the straight-line equation for p and t we have

$$\frac{dp}{aT} = \frac{A}{mT^2}$$

where m is the modulus of the ordinary system of logarithms (0.4243).

Combining these, we have

$$\begin{aligned} L &= \frac{R}{m} \mathrm{A} \\ &= 4.57\, A \end{aligned}$$

It follows, that A furnishes us with the latent heat of vaporization, and that the straight-line equation makes this quantity a constant, at all temperatures. This is not a fact of nature, since we know that the latent heat of vaporization changes with the temperature, because of the difference of specific heats of the gaseous and liquid material, that it increases slowly going towards low pressures, and decreases fast at high pressures, becoming zero at the critical point. The straight line is therefore only a sector of a curve, drawn through two points of a curve which is convex towards the axis T, and which gives the average value of the latent heat of vaporization ($4.57A$), for the temperature range between the points which have been used to determine the equation.

Since, however, the straight line does fit quite satisfactorily most of the actual determinations of vapor tensions of the metals which have been made, it follows that at these comparatively low pressures, far removed from the critical temperature, the latent heat of vaporization does not vary very much, is approximately constant, and can be derived from the vapor tension equation.

TROUTON'S RULE.

Trouton found that the molecular latent heat of vaporization at normal atmospheric pressure was a function of the absolute temperature of the normal boiling point. Numerically it averages 23 T. Nernst maintains that the 23 is not a constant, but varies somewhat with the temperature, being as low as 15 for substances boiling at very low temperatures and as high as 29 for those boiling at very high temperatures. It seems to be true, however, that for many substances boiling between 0° C. and 500° C., the constant is between 20 and 25, and averages 23. Substituting normal atmospheric pressure in the straight-line equation, and 23 T for 4.57 A, we would find that B was fixed, since

$$B = \log. p + \frac{A}{T} = 2.88 + \frac{23\,T}{4.57\,T} = 7.90$$

This is in pretty good agreement with the average value of B, 8.03, derived directly from the actual straight-line equation for ten different metals, on a previous page, using the experimental values. If we assume $B = 8.03$, and work the equation backwards, Trouton's constant would figure out 23.85. I have concluded to use the values 23 and 7.90 for low boiling-point metals (500°–1500° C.), and 25 and 8.4 for high boiling-point metals (over 1500° C.).

RICHARDS' RULE.

A rule similar to Trouton's was discovered by the writer concerning the latent heat of fusion, *viz.*, the molecular latent heat of fusion is approximately 2.1 T, where T is the absolute melting point. This observation is useful in deriving the straight-line relation for the sublimation of a solid metal below its melting point.

$$\log. p = \frac{A'}{T} + B'$$

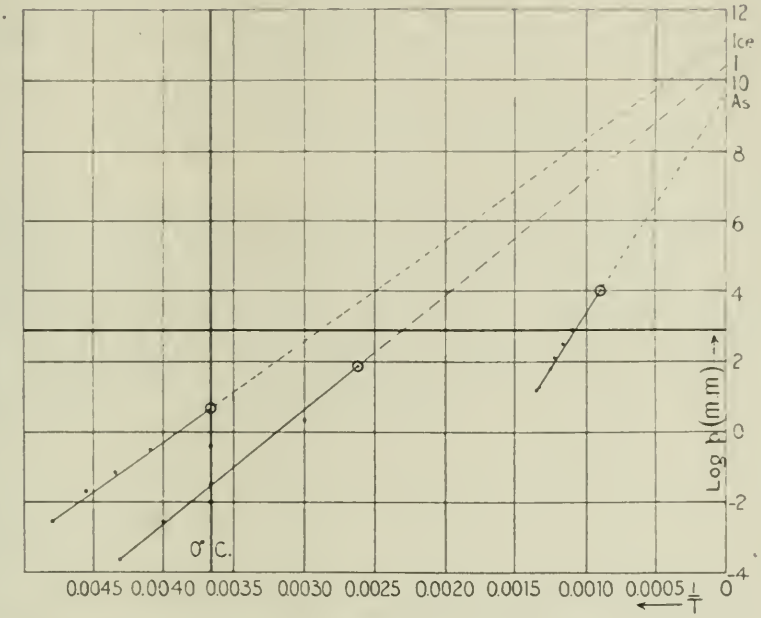
In this equation, 4.57 A' is the latent heat of sublimation, and a study of the rather scanty data on the vapor tension of solid substances shows that such an equation fits satisfactorily the experimental data. Fig. 3 shows this for ice, iodine and arsenic.

Since the latent heat of sublimation equals the sum of the latent heat of vaporization of the liquid and the latent heat of fusion, then

$$4.57\,A' = 4.57\,A + L\text{ fusion}$$
$$A' = A + \frac{L\text{ fusion}}{4.57}$$

If the latent heat of fusion of a metal is known, we express it per molecular (= atomic) weight, divide by 4.57 and add the quotient to A to get A'.

FIG. 3.



Since at the melting point the vapor tensions of the solid and the liquid are alike, if we substitute $T_{m.p.}$ in the two equations under consideration, we have

$$\log.\ p_{m.p.} = -\frac{A'}{T_{m.p}} + B' = -\frac{A}{T_{m.p}} + B$$

Whence

$$B' = \frac{A' - A}{T_{m.p}} + B$$
$$= B + \frac{L\text{ fusion}}{4.57\,T_{m.p}}$$

If the latent heat of fusion is known, B' can thus be calculated, and we have the complete vapor tension line for the solid state.

If the latent heat of fusion is not known, we may put it, as a first approximation, as equal to 2.1 $T_{m.p.}$ We then have

$$A' = A + \frac{2.1\ T_{m.p.}}{4.57} = A + 0.46\ T_{m.p.}$$

$$B' = B + \frac{2.1\ T_{m.p.}}{4.57\ T_{m.p.}} = B + 0.46$$

Richards' rule would therefore enable us to pass from the vapor tension equation for the liquid state to that for the solid state, and *vice versa*, if merely the melting point is known, without knowing experimentally the latent heat of fusion. In a few cases, *e.g.*, arsenic, both equations can be determined from experimental data. Taking these empirical equations for arsenic, we have

$$\begin{aligned} A' - A &= 5610 - 5115 = 495 = 0.45\ T_{m.p.} \\ B' - B &= 9.10 - 8.65 \qquad\quad = 0.45 \end{aligned}$$

which is a striking confirmation of the approximate accuracy of the 0.46 $T_{m.p.}$ and 0.46 deduced by applying Richards' rule.

It results, therefore, from the above discussions, that given two determinations of vapor tension and temperature, we can determine a straight-line relation between them; if this is for the liquid state we can pass over to the similar equation for the solid state if we know the melting point and latent heat of fusion, and *vice versa*. If we have only one such determination, in either the liquid or solid state, we can assume B or B', and then work out A or A' and thence the whole of both equations. If we do not know the latent heat of fusion, it may be assumed as equal to 2.1 $T_{m.p.}$, and then the complete scheme worked out. Finally, if we do not have a single vapor tension determination, but know the latent heat of vaporization (of the liquid) or the latent heat of sublimation (of the solid) we could work out a first approximation to the vapor tension equation for the liquid or the solid state; if we know the melting point, we can pass from one to the calculation of the other.

Table I gives the vapor tensions of the metals, and a few non-metals, as far as their straight-line equations can be determined, either from the experimental data, or by assumption of values of the constant B. These data are in many cases only first approximations, but they are also, in not a few cases, the first attempts to get an idea of the order of magnitude of these vapor tensions, and therefore deserve some serious consideration even if they cannot be considered as accurate.

Table II gives several estimated and a few observed values of the latent heats of vaporization of some elements, mostly metals. Since the experimental values are mostly lacking for the metals, the calculated or estimated values, using Trouton's rule, are of considerable value as first approximations, even though we know they cannot be strictly accurate.

THE TRUE VAPOR TENSION CURVE.

From the experimental data regarding the vapor pressures of the metals we are not justified in deducing formulas of more than two terms—the straight-line formulas already discussed (with the single exception of mercury, whose vapor tension has been minutely studied)—yet for mercury and some non-metals, whose vapor tensions are more accurately known, the true vapor tension curve, as developed by Nernst, may be constructed.

It is therefore *apropos* to state this true curve, in order that it may be used for mercury and for any other metal for which the experimental data are sufficiently accurate.

The more accurate relationship is

$$log.\, p = -\frac{A}{T} + 1.75\, lcg.\, T - C\,T + D$$

The three constants of this equation A, C and D are not the same as A and B of the straight-line formula above discussed, but 4.57 A of this equation represents the latent heat of vaporization of the substance for $T = O$; a wholly theoretical quantity.

The formula requires for its determination only three observations of vapor tensions at three different temperatures. They must be accurate enough to fix the form of the curve and the three constants.

The differentiation of this formula for dp, and substitution of this in the Clausius expression for L, the latent heat of vaporization, gives

$$L = 4.57\,[A + 0.743\,T - C\,T^2]$$

This formula is true only for moderate pressures, far removed from the critical temperature, where the volume of the liquid is negligible in comparison with the volume of the gas which it forms. At high pressures, where the volume (and density) of the vapor approximates the volume (and density) of the liquid, the formula is not accurate for two reasons: (1) The density of

TABLE I.

Vapor Tensions of the Metals.

In the Solid and Liquid States, at Their Melting Points, and at 0° C. p = mm. Hg., *T = Degrees Absolute = °K.*

	Solid log. $p = -\frac{A'}{T} + B'$		At 0° C. mm. Hg.	At *M. P.* mm. Hg.	Liquid log. $p = -\frac{A}{T} + B$	
	A'	B'			A	B
H_2	.....	....	....	....	51.5	5.4
Br_2	.....	....	66	45	1635	7.8
I_3	3458	10.43	2×10^{-2}	89	2390	8.1
P_3	2260	7.34	0.115	1.63	2160	7.0
Hg	3170	8.26	0.0002	5.13×10^{-6}	3069	7.75
S_8	4140	9.15	1×10^{-6}	0.028	3745	8.1
As_3	5610	9.10	2.8×10^{-21}	10,000	5115	8.65
Se_3	5250	8.56	2.1×10^{-11}	0.71	5025	8.1
Cs	4900	8.35	2.5×10^{-10}	1.2×10^{-8}	4760	7.92
K	5300	8.26	7.1×10^{-12}	2.25×10^{-8}	5190	7.92
Rb	5040	8.28	6.7×10^{-11}	1.5×10^{-8}	4890	7.90
Cd	6470	9.28	3.8×10^{-15}	2.6×10^{-2}	6151	8.74
Na	4700	7.30	8.1×10^{-9}	3.55×10^{-6}	4565	6.85
Zn	6685	8.63	1.03×10^{-16}	9.3×10^{-2}	6365	8.17
Mg	8060	8.81	5.25×10^{-20}	1.15	7690	8.4
Te_2	10,230	9.84	8.1×10^{-32}	6.3×10^{-5}	9180	8.4
Bi	10,000	8.45	6.6×10^{-29}	$1. \times 10^{-10}$	9460	7.45
Sb_3	10,850	9.58	6.5×10^{-31}	3.55×10^{-3}	9790	8.4
Tl	10,260	8.5	8.3×10^{-30}	4.7×10^{-10}	9940	7.92
Li	8900	8.38	$6. \times 10^{-25}$	4.9×10^{-12}	8690	7.92
Pb	9744	8.41	4.9×10^{-28}	1.5×10^{-8}	9500	8.0
Mn	12,650	8.85	3.2×10^{-38}	1.98	11,195	8.4
Ag	12,180	8.36	5.6×10^{-37}	3.2×10^{-2}	11,600	7.9
Ni	14,245	8.90	5.25×10^{-44}	4.36	13,375	8.4
Al	14,190	8.98	1.0×10^{-43}	5.25×10^{-7}	13,650	8.4
Si_2	15,530	9.0	8.0×10^{-47}	1.32	14,200	8.4
Cr	14,460	8.86	7.8×10^{-45}	4.47	13,650	8.4
Sn	14,420	9.1	5.6×10^{-44}	6.3×10^{-20}	13,930	8.4
Cu	15,765	9.17	2.6×10^{-49}	3.5×10^{-3}	15,160	8.75
Fe	15,840	8.84	6.9×10^{-50}	1.20	15,030	8.4
Pt	16,250	9.0	3.0×10^{-51}	9.55	15,040	8.4
Ti	16,090	8.85	8.3×10^{-49}	11.75	15,170	8.4
Rh	16,500	8.94	3.2×10^{-52}	38	15,300	8.4
Ru	16,450	8.86	4.0×10^{-52}	28.8	15,420	8.4
Au	16,175	8.93	4.8×10^{-51}	6.8×10^{-4}	15,470	8.4
Pd	16,340	8.85	1.4×10^{-60}	0.78	15,500	8.4
Ir	16,670	8.81	5.6×10^{-53}	302	15,580	8.4
Os	16,880	8.81	9.6×10^{-54}	97.7	15,870	8.4
U	17,975	8.85	1.0×10^{-57}	5.5×10^{-6}	17,400	8.4
Mo	22,650	8.85	7.6×10^{-75}	4.9	21,380	8.4
B_2	21,230	8.36	3.9×10^{-70}	5.0	19,950	7.92
C_2	24,300	9.0	1.0×10^{-80}	6,310	22,195	8.5
W	31,670	8.86	7.4×10^{-108}	1.3	30,000	8.4

TABLE II.

Latent Heats of Vaporization.

	B. P. C.°	*B. P.* K.°	Trouton's Rule 23 *T* (Molecular)	Calc. by Trouton's Rule (per Kg.)	Observed (per Kg.)	Calc. from Vapor Tension Curve (per Kg.)
H_2	—253	20	460	230	. . .	118
N_2	—196	77	1771	63	50	54
O_2	—188	85	1955	61	58	52
Cl_2	—22	251	5773	81	67	72
Br_2	58	331	7613	48	46	. . . .
I_3	174	447	10,280	27	24	. . . .
P_3	287	560	12,880	138	130	. . . .
Hg	357	630	14,490	72	68	67
S_3	444	717	16,390	64	72	. . . .
As_3	450	723	16,625	74	. . . .	. . . .
As_3	616	889	[22,225]	99	. . . .	114
Se_3	690	963	22,150	94	. . . .	97
K	757	1030	23,690	607	. . . .	. . . .
Cd	778	1051	24,170	216	181?	251
Na	877	1150	26,450	1150	. . . .	905
Zn	930	1203	27,670	426	366?	446
Mg	1120	1393	32,040	1335	1700?	1443
Te_2	1390	1663	38,250	151	. . . .	166
Bi	1435	1708	39,280	189	162?	208
Sb_3	1500	1773	41,480	115	. . . .	124
Tl	1700	1973	45,380	222	. . . .	. . . .
Li	1450	1723	39,630	5,660	. . . .	. . . .
Pb	1580	1853	41,820	202	. . . .	209
Mn . . .	1900	2173	49,980	909	. . . .	995
Ag	2040	2313	53,200	493	. . . .	490
Ni	2150	2423	55,730	953	. . . .	1042
Al	2200	2473	56,880	2107	. . . .	2305
Si_2	2200	2473	56,880	1015	1262	1153
Cr	2200	2473	56,880	1094	. . . .	1197
Sn	2250	2523	58,030	492	. . . .	538
Cu	2310	2583	59,410	934	. . . .	1087
Fe	2450	2723	62,630	1118	. . . .	1224
Pt	2450	2723	62,630	318	. . . .	351
Ti	2475	2748	63,200	1317	. . . .	1431
Rh	2500	2773	63,780	619	. . . .	677
Ru	2515	2788	64,120	629	. . . .	689
Au	2530	2803	64,470	327	. . . .	358
Pd	2535	2808	64,580	606	. . . .	667
Ir	2545	2818	64,810	336	. . . .	368
Os	2600	2873	66,080	346	. . . .	379
U	2900	3173	72,980	305	. . . .	333
Mo	3600	3873	89,780	935	. . . .	1015
B_2	3700	3973	91,380	4155	. . . .	. . . .
C_2	3700	3973	99,325	4140	. . . .	. . . .
W	5200	5473	125,880	684	. . . .	. . . .

the gas no longer obeys Boyle's law; (2) the density of the liquid increases because of the great pressure. The formula is very applicable, however, to all ordinary temperatures and pressures. Worked out for mercury, at 760 mm. pressure, it gives 66.8 calories per gram, whereas experiment shows 67.8 cal.; for 0° C. it gives 77.1 cal.

PRACTICAL APPLICATIONS.

Distillation of Metals.—Some metals are obtained entirely by distillation from their ores, escaping from the reduction furnaces entirely as vapor. Such is the case with mercury, cadmium and zinc. In these cases, the useful work performed by the furnace is not entirely known until the heat in the vapor of the metals is known. For mercury this item is not large, but it is considerable for cadmium and still greater for zinc. In fact, for zinc it forms a material part, some 25 per cent., of the total thermal work done in the furnace. It is only recently that the latent heat of vaporization of zinc has been experimentally determined; up to that time we could use only the value derived from the vapor tension curve or by use of Trouton's rule. In electric furnaces large quantities of high boiling-point metals are volatilized, and thus consume a large proportion of the expensive electric power required to run them; a silicon furnace is a good example of this, where as much as 25 per cent. of the reduced silicon may be vaporized out of the furnace. We can get a first approximation to these losses of power by studying the vapor pressures of these metals and thus their latent heats of vaporization.

According to the principle of partial pressures of the constituent gases in mixtures, the metallic vapors may be at small fractions of atmospheric pressure when mixed with other inert gases. The problem of condensing these vapors is then complicated by the fact that they do not commence to condense at their normal boiling points, but only at much lower temperatures corresponding to their partial pressures in the gas mixture. This dew point, as it may be properly called (since the principle involved is exactly similar to the deposition of water as condensed moisture, or dew, from moist air) is often at unexpectedly low temperatures, and the more dilute the gas mixture the lower the condensing temperature. Gases from the mercury furnace are sometimes only 1 per cent. mercury vapor, and their dew point may be 150° to 200° C. instead of 357°, the condensing point of pure mercury vapor. The whole phenomena of condensation of metallic vapors, including the heat liberated in the condensation as well as the per cent. of the metallic vapor condensed, depend for their study and investigation on the correct use of vapor tension data.

When zinc-lead-silver-gold skums from the Parkes process are distilled, the first zinc coming off is nearly pure, but as the zinc present in the alloy decreases a higher and higher temperature is required to drive it off, at atmospheric pressure, until the last part of the zinc comes off only at the maximum temperature of the furnace, some 1300° C. Successively larger amounts of lead, silver and gold come over the higher the temperature and the lower the proportion of zinc in the alloy. All these phenomena are governed by the vapor tensions of the respective metals, and the principle that they exert fractions of their maximum tensions proportional to the relative *molecular* proportions of each present in the alloy. Interesting and practically valuable calculations can thus be made. The temperature necessary to reach in order to attain any given purity of the residual alloy or metal can be thus calculated, as also the composition of the condensed vapors. The composition of the condensate is very different from that of the residuum; the former approximates to equal molecular weights (atomic weights) of the metals present; the latter to one single metal (the least volatile), almost pure, with decreasing amounts of the impurities according to their greater volatilities.

Zinc Losses in Brass Melting.—Considerable zinc is lost in making and melting brass. The normal boiling point of zinc is 930° C., yet brass is usually made and cast at 1000° to 1200° C. We are spared the loss of all the zinc by two facts: (1) The molecular (atomic) proportion of the zinc present is 15 to 30 per cent., which means that at any given temperature the zinc in this alloy can exert only 15 to 30 per cent. of the maximum vapor tension of pure zinc at that temperature; (2) the copper and zinc unite with some energy, and the energy of that combination also retards the volatilization of the zinc and lowers still more its vapor pressure. Owing to these two circumstances, the vapor tension of zinc from brass is usually less than atmospheric tension at operating temperatures, and therefore the losses are not excessive.

If the vapor tension of pure zinc is

$$\log. p = -\frac{6365}{T} + 8.17$$

then if the atomic fraction of zinc present in the alloy is f, the vapor tension relation becomes

$$log.\ p + log.\ f = -\frac{6375}{T} + 8.17$$

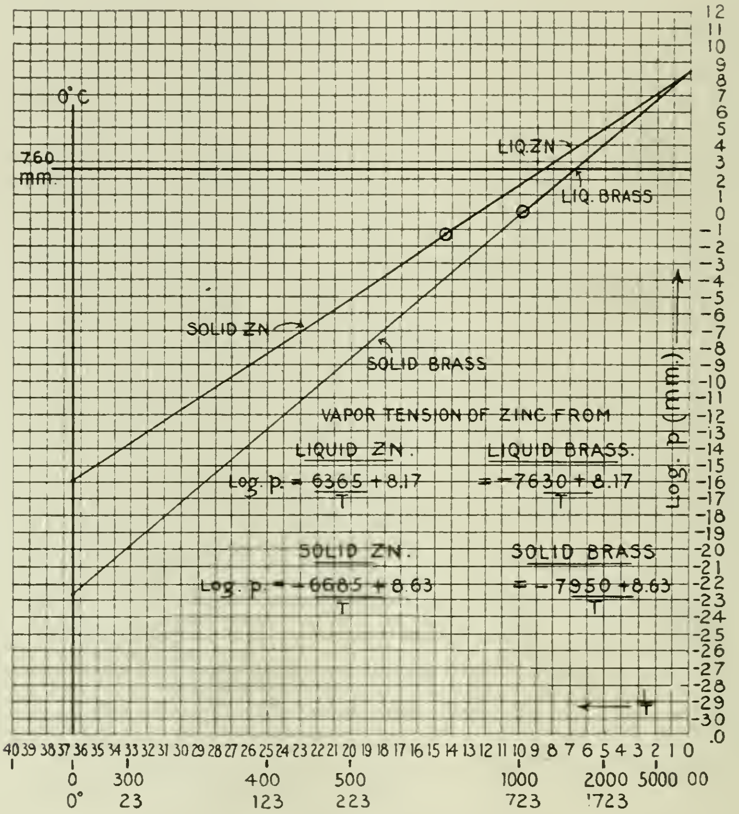
Further, if the zinc atom unites with copper with evolution of the energy Q $(Cu_x, Zn = Q)$, this energy must be added to the work done in the vaporization of the zinc, and we have

$$log.\ p + log.\ f = -\frac{6365 + Q/4.57}{T} + 8.17$$

as the complete expression for the vapor tension of zinc from brass.

This equation, if Q were known for different grades of brass, would be of considerable use in the scientific development of the brass industry (Fig. 4).

Fig. 4.



Loss of Metals as Fume.—This subject is of great importance with metals of high value, such as silver, gold and platinum, where comparatively small losses in weight represent large losses in value. Even in such a simple operation as melting silver, if the heating is done by a flame coming in contact with the metal, the vaporization losses even from the *solid* metal, before it melts, may be considerable. This is a phenomenon strictly analogous to the vaporization (sublimation) of ice in a current of dry air at temperatures below the freezing point. To estimate its amount, we must know the vapor tension of solid silver below its melting point. While melting, and at higher temperatures, considerably more silver is volatilized, and the vapor tension curve enables us to calculate the amounts for different temperatures of the gases in contact with it.

One firm, using the tabulated vapor tensions, and measuring carefully the temperatures and amounts of the gases going through its furnaces, calculated that it was vaporizing about $30,000 worth of silver per year. On the strength of this calculation they put in a Cottrell electrostatic precipitation plant (costing $25,000), and in the first year of its operation collected just $30,000 worth of silver from the fume.

Sherardizing and Calorizing.—These are processes which coat iron or other metals with zinc or aluminum respectively, by heating the iron objects to a moderate temperature, below the respective melting points of zinc and aluminum, until their surface has absorbed the desired amount of coating.

Sherardizing was invented first, and has already come into large use as a competitor of ordinary galvanizing. The zinc soaks into the surface of the iron like ink into blotting paper, adding to the weight of the object but not to its external dimensions, and leaving perfectly sharp and unchanged screw threads or other superficial characteristics. The whole operation depends on the formation of zinc vapor from the solid zinc dust and its absorption by the iron. The vapor tension curve of solid zinc, at the temperatures used, gives a quantitative explanation of the rate of absorption with change of temperature, and therefore serves as a practical guide in studying and operating the process.

Calorizing is operated at still lower metallic vapor pressures, because of the high normal boiling point of aluminum, yet while about 0.1 mm. (Hg) pressure of zinc vapor effects Sherardizing, not over 0.000001 mm. (Hg) of aluminum vapor effects calorizing.

A study of the vapor tensions of metals at their melting points will show which are best able to act like zinc and aluminum in a similar manner, for metal plating purposes.

Vapor Losses During Electrolysis.—We will consider finally the question of losses of metal at the cathode during electrolysis of melted salts, using melted metal as cathode. The production of aluminum is a good example. Here, the ampere efficiency of metal obtained is 75 to 90 per cent. of the metal actually deposited; the loss is due to the phenomenon of metallic mist or fog or vapor, called *metallische Schleier* by Lorenz, of Zurich, who investigated it most fully.

There seems to be strong evidence for believing that these large percentage losses are connected directly with the vapor tension of the molten metal. Lorenz was handicapped in his discussion by very inadequate data as to the vapor tensions of these metals at the temperatures in question, which are not far above their melting points.

We may indulge the hope that the approximate values of the vapor tensions deduced by us may be of use also in this field, in helping to a better understanding of these losses and possibly in helping to reduce or to obviate them.

"Vest-pocket" Camera for Commercial Photography. Anon. (*British Journal of Photography,* vol. lxvi, No. 3070, p. 109, March 7, 1919.)—There are occasions when a high-grade small camera, far from being a toy, may be of very real service to the photographer placed in exceptional circumstances. The fact that these instruments are fitted with lenses of short focus and wide aperture, and thus give good definition over many varied planes of distance without recourse to stopping down may often be of real service. A case in illustration of this point was told some time ago by a commercial worker. He was commissioned to make a series of pictures of certain pieces of machinery in a factory which was rather poorly lighted. As the work would have necessitated the use of a lens well stopped down in order to gain the required definition, and as the stoppage of the machinery was an important factor, the operator took with him a vest-pocket camera. This he found gave all the definition required, and fine definition without stopping down the lens. The result was that the pictures were taken in a very short time, as the worker was enabled to use the lens working at f/6 instead of one stopped down to f/22. Enlarged prints were made that gave the customer entire satisfaction.

HOW THE NITROGEN PROBLEM HAS BEEN SOLVED.* †

BY

HENRY JERMAIN MAUDE CREIGHTON,

Department of Chemistry, Swarthmore College,
Member of the Institute.

III. THE ABSORPTION OF NITROGEN BY CARBIDES; THE CYANAMIDE PROCESS.

In 1894 the attention of the technical world was focussed upon the invention of Moissan and Wilson, which led to the manufacture of calcium carbide in the electric furnace on a large scale. A short time afterwards, Frank and Caro made the discovery that while barium carbide could readily be made to combine with atmospheric nitrogen at high temperatures to form barium cyanide, but small quantities of cyanide could be formed with calcium carbide under the same conditions, notwithstanding the fact that there was apparently a large absorption of nitrogen. This striking result led to a closer examination of the reaction product, and it was found that most of the nitrogen absorbed by the carbide had been converted into calcium cyanamide. From a technical standpoint, the absorption of nitrogen by calcium carbide at high temperatures is of the greatest significance, and constitutes one of the most important means for the fixation of atmospheric nitrogen.

OUTLINE OF THE PRINCIPLES UNDERLYING THE FORMATION OF CALCIUM CYANAMIDE FROM CALCIUM CARBIDE AND ATMOSPHERIC NITROGEN.

Although the reaction between calcium carbide and nitrogen is usually expressed by the simple reversible equation:

$$(12)\quad CaC_2 + N_2 \rightleftarrows CaCN_2 + C,$$

in reality it is so complicated that up to the present all attempts to establish its equilibrium constants have been unsuccessful. If calcium carbide, calcium cyanamide and carbon are regarded as solid phases, the system should be monovariant, and there should be a definite pressure corresponding to a given temperature. Should the pressure exceed this equilibrium value, then nitrogen must be absorbed by the carbide, while if the pressure should be less than this value, then calcium cyanamide must react with the carbon to re-form calcium carbide and nitrogen.

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* Communicated by Professor Creighton.

† Continued from page 408, Vol. 187, April, 1919.

Attempts to measure the equilibrium of the reaction have produced very conflicting results. Thus, the equilibrium temperature corresponding to a pressure of one atmosphere is given as 1700° C. by Thompon and Lombard, as 1360° C. by Caro, and as 1100° by Matignon. This lack of agreement has been ascribed to a number of different causes, among which may be mentioned the chemical inertness of nitrogen; the impurities present which probably take part in the reaction; the disturbance of the equilibrium caused by sublimation of the calcium cyanamide; and still more fundamental, the fact that probably during the reaction calcium carbide dissociates into carbon and a lower carbide.

The azotization of calcium carbide is a strongly exothermic reaction. So much heat is liberated during the initial stages of the reaction that the reaction mass is raised to between 1000° C. and 1100° C., the temperature necessary for satisfactory azotization.

The rate at which nitrogen is absorbed by commercial calcium carbide varies with the temperature at which azotization takes place, a temperature of at least 1000° C. being necessary for rapid and complete azotization. Below this temperature, the absorption of nitrogen is limited and takes place slowly. The influence of temperature on the rate of absorption is illustrated graphically by the full curves in Fig. 15, for nitrogen under a water pressure of 132 mm. The rate of azotization also increases with the pressure up to about two atmospheres, but further increase in pressure produces little change in the rate at which the gas is absorbed.

Moissan has shown that pure calcium carbide is quite inert towards nitrogen at a temperature of 1200° C. The ease with which the commercial carbide absorbs nitrogen at this temperature is due to the presence of 10 to 15 per cent. of lime and other impurities which act as catalysts.

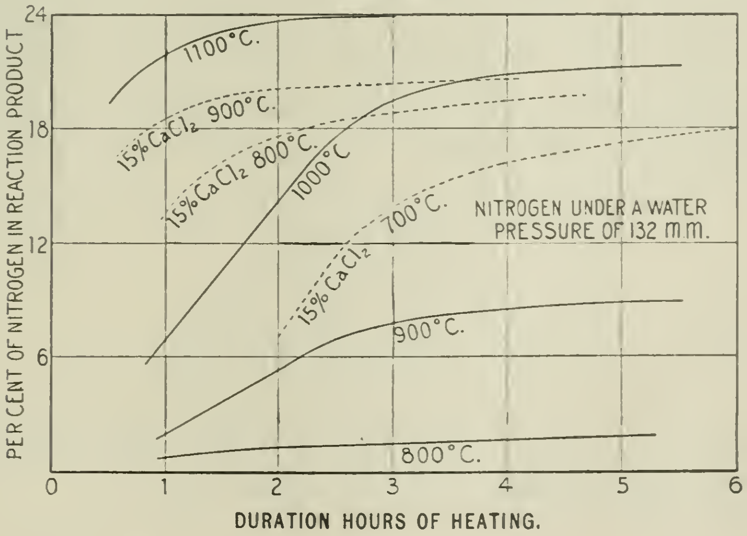
It has been found that if certain substances are admixed with commercial calcium carbide, the rate of azotization is markedly increased, and the minimum initial reaction temperature is lowered. For metals of the same periodic group, the acceleration is greater the lower the atomic weight. Of the many addition substances studied, the most effective is calcium chloride, as is shown by the data contained in Table VIII, in which is given the per cent. of nitrogen absorbed in two hours at 800.°

TABLE VIII.

Addition Substance.	Per cent. nitrogen absorbed.
None	3.2
10 per cent. CaO	4.0
10 per cent. Na_2CO_3	8.5
10 per cent. NaCl	13
10 per cent. $CaCl_2$	22

Calcium chloride lowers the reaction temperature to such an extent that a rapid absorption of nitrogen takes place at temperatures from 700° C. upwards. The rate of absorption increases with the content of the chloride up to 30 per cent., although its effect becomes less marked as the percentage increases. With calcium fluoride the reaction temperature is not brought so low as in the case of the chloride, and an addition of from 2 to 5 per cent. is most favorable. The rate of azotization of calcium carbide at different temperatures in the presence of 15 per cent. of calcium chloride is shown by the broken curves in Fig. 15.

FIG. 15.



The ultimate cause of the increased azotization of calcium carbide by these addition substances (including the lime always present in the commercial carbide) is probably due to their assisting the reaction by the removal of the film of calcium cyanamide from the carbide, and to their softening the reaction mass, thus increasing its power of taking up nitrogen. The immediate cause is more obscure, but is probably related to the rate of decomposition of the carbide into carbon and a sub-carbide,

$$(13)\quad CaC_2 \rightleftarrows CaC + C,$$

and the absorption of nitrogen by the latter,

$$(13a)\quad CaC + N_2 \rightleftarrows CaCN_2.$$

THE TECHNICAL PRODUCTION OF CYANAMIDE.*

The calcium carbide employed in the manufacture of cyanamide is prepared from lime and coke in the electric furnace, and is usually about 80 per cent. pure. After cooling, the carbide is ground in air-tight apparatus filled with nitrogen, so that it passes a hundred-mesh screen. As carbide of this fineness is almost as explosive as low-grade dynamite when exposed to the atmosphere on a damp day, the operation of grinding presents a problem.

The nitrogen used in the manufacture of cyanamide is obtained at the present time either by the fractional distillation of liquid air, or by the copper oxide process. As the gas must be of a high degree of purity, it has to be freed from water vapor, the oxides of carbon, and oxygen. On no account should the oxygen present exceed 0.4 per cent. Water vapor and oxygen react with the carbide and the carbon resistances of the furnace, in accordance with the following equations:

$$(14)\quad 2C + O_2 = 2CO;$$
$$(15)\quad C + H_2O = CO + H_2;$$
$$(16)\quad CO + CaC_2 = CaO + 3C;$$
$$(17)\quad H_2O + CaC_2 = CaO + C_2H_2;$$
$$(18)\quad 3O_2 + 2CaC_2 = 2CaO + 4CO.$$

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* In this paper the term "cyanamide" is used to denote the commercial product, the chief component of which is $CaCN_2$, and not to denote the compound $CN.NH_2$.

The finely ground carbide is transferred to iron retorts having a capacity of from one-half to two and one-half tons. By employing small units a uniform temperature and, therefore, a more reliable product, can be obtained. The retorts are next placed in the "furnace," consisting of a gas-tight, horizontal channel, the roof of which is removable to allow of the handling of the retorts. Pure nitrogen is then admitted into the channel of the furnace under a pressure slightly in excess of one atmosphere, so as to overcome any tendency of air to enter.

The retorts are heated electrically by means of carbon resistances. Each retort contains a central carbon rod, or several connected in series. When the retorts are in position, the resistances are connected electrically to suitable permanent terminals in the furnace. With the electric method of heating, difficulties arising from strong sintering of the material and its adhesion to the walls of the retort are avoided.

After all the air has been expelled from the retorts, the electric current is turned on. Each retort requires from 65 to 75 volts. It is probable that a number of units are connected in parallel, and that a low current, *e.g.*, 20 amperes, is employed. The retorts are heated for thirty or forty hours, during which time the temperature in the outermost layers of the reaction mass rises to about 1000° C. The current is then interrupted and the reaction allowed to complete itself, the end being indicated by the pressure registered by a manometer in the nitrogen pipe line.

The crude cyanamide when taken from the furnace usually contains 63 per cent. calcium cyanamide, corresponding to 22 per cent. nitrogen, 12 per cent. lime, 12 per cent. carbon in the form of graphite, 1 per cent. unazotized carbide, 1 per cent. calcium sulphide, 2 per cent. iron and alumina, and 2 per cent. silica. On cooling, the cyanamide is ground in an atmosphere of nitrogen to a fine powder. During this operation, great precautions are taken to prevent explosions due to the presence of acetylene derived from the unazotized carbide.

PRODUCTION OF AMMONIA FROM CYANAMIDE.

On treating cyanamide with superheated steam, ammonia is produced in accordance with the equation:

$$(19)\quad CaCN_2 + 3H_2O = CaCO_3 + 2NH_3.$$

Under proper conditions the reaction is almost quantitative. The rate at which ammonia is formed increases with temperature, as is shown by the data in Table IX.

TABLE IX.

Temperature ° C.	Per cent. nitrogen converted into ammonia at the end of:	
	15 minutes.	45 minutes.
120°	11.3	31
160°	45.8	83.7
180°	75.2	....

The reaction follows the monomolecular equation, the velocity constant at different temperatures having the following values: 0.00362 at 120° C., 0.0046 at 130° C., 0.00687 at 140° C., 0.0111 at 150° C., 0.0177 at 160° C., 0.027 at 170° C. and 0.0403 at 180° C.

The reaction is exothermic, and the heat developed is sufficient to cause the process to proceed of itself at a high velocity, when once it has started. In order to take advantage of this heat development, the reaction is carried out in steel autoclaves, 8 feet in diameter and 20 feet high, capable of operating under a working pressure of 300 pounds per square inch. In each autoclave is placed about 12,000 pounds of mother liquor derived from a previous operation (fresh water to start), and the finely ground cyanamide slowly fed into this liquor under continuous agitation by a powerful stirring apparatus with which each autoclave is provided. Any acetylene evolved during this operation is removed by a suitable ventilating system. In order to insure thorough incorporation of the cyanamide, the charging of the autoclaves is usually carried out over a period of an hour. Lime and soda are next added. These substances increase the efficiency of the ammonia evolution, principally through the prevention of the formation of polymeric forms of cyanamide compounds which are difficult to transform into ammonia. The autoclaves are then closed and superheated steam admitted until the pressure gauge registers 3 or 4 atmospheres. The temperature is then sufficiently high to start the reaction at a fair rate of speed, after which it proceeds of itself. As the temperature rises the gas pressure is relieved by means of valves through which the gas is discharged, the rate being so regulated as to maintain a constant pressure on the ammonia line. The evolution of ammonia usually continues for about one and one-half hours. While nearly all of the cyanamide is decomposed during this operation, the steaming is usually repeated a second, and even a third time.

The ammonia-steam mixture which comes from the autoclaves is passed through a simple rectifying column provided with a dephlegmator and condenser, from which is obtained ammonia, saturated with water vapor, having a very high degree of purity.

PRODUCTION, ENERGY REQUIREMENTS AND COSTS.

During the past few years the production of cyanamide has increased very rapidly, furnishing in 1918 about one-fifth of the world's fixed nitrogen. The present annual producing capacity of different countries is as follows [5]:

Germany	500,000 Tons
France	300,000 Tons
United States (Muscle Shoals)	220,000 Tons
Norway and Sweden	220,000 Tons
Canada (Niagara Falls)	64,000 Tons
Italy	60,000 Tons
Japan	50,000 Tons

Aside from the preparation of nitrogen, the electrical energy requirements in the manufacture of cyanamide amount to 16.6 kilowatt hours per kilogram of nitrogen fixed, or to 1 kilowatt hour per 100 grams of cyanamide produced. The cost of conversion of cyanamide to ammonia has been estimated (on a pre-war basis) at one and one-half cents per pound of ammonia, and the total cost of ammonia by the cyanamide process, with power at $8 per horse-power year, at one to two cents more than by the Haber process.

ADVANTAGES AND DISADVANTAGES.

The chief advantages of the fixation of atmospheric nitrogen by carbides, as represented by the cyanamide process, are:

1. Moderate power requirements.
2. Easy transportability.
3. Product may be used as a fertilizer or for the production of ammonia of a very high degree of purity.

The chief disadvantages of the process are:

1. Number of operations involved, especially if it is required

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[5] The writer wishes to acknowledge his indebtedness to Mr. E. J. Pranke, of the American Cyanamide Company, for the figures.

to produce nitric acid, *viz.,* production of carbide, production of pure nitrogen, production of cyanamide, decomposition of cyanamide to ammonia, oxidation of ammonia, absorption of nitrous gases, and the concentration of dilute nitric acid.

2. Process is extremely dusty and disagreeable.
3. Large labor factor involved.
4. Comparatively high cost.

IV. THE ABSORPTION OF NITROGEN BY METALS IN THE FORM OF NITRIDES.

Since many metals, such as titanium, aluminium, lithium, magnesium, etc., readily combine with nitrogen to form nitrides from which ammonia is easily obtained, this class of compounds has been extensively studied during recent years, with a view towards determining whether they could be employed for the commercial fixation of atmospheric nitrogen.

The normal nitride of titanium, TiN_2, on being heated in a current of hydrogen, yields nearly one-half of its nitrogen in the form of ammonia. The residual lower nitride, TiN, on being heated in an atmosphere of nitrogen is converted back into the normal nitride. Repeated attempts have been made in France to build up an industrial process for the manufacture of ammonia on the basis of this reaction, but without success. Some years ago, H. B. Landmark claimed to have perfected a continuous process for the manufacture of ammonia from this nitride, based upon the reaction expressed by the equation:

$$(20) \quad 2TiN_2 + 3C + 3H_2O \rightleftarrows 2TiN + 3CO + 2NH_3.$$

Steam is passed over a heated mixture of the nitride and carbon. By substituting a current of nitrogen for steam the normal nitride is regenerated; by employing a current of steam in place of the nitrogen, the operation becomes continuous, requiring from time to time a renewal of the supply of carbon. Essentially the titanium acts as a catalytic agent.

Ottokar Serpek was the first to recognize the possibility of applying the reaction between aluminium and nitrogen to the fixation of atmospheric nitrogen. The manufacture of aluminium nitride has received considerable attention because of the ease with which it can be converted into ammonia, and because of the possible importance for the aluminium industry of the alumina obtained as a by-product. Indeed this is the only process depending on the formation of a metallic nitride which, at the present time, seems to offer prospects of technical success for the fixation of atmospheric nitrogen. Though the process was in operation in a small way at Saint Jean de Maurienne, in Savoy, and two large semi-commercial installations are at present being tested in this country, at the present time it must be regarded as an unproven process.

THE TECHNICAL PRODUCTION OF ALUMINIUM NITRIDE BY THE SERPEK PROCESS.

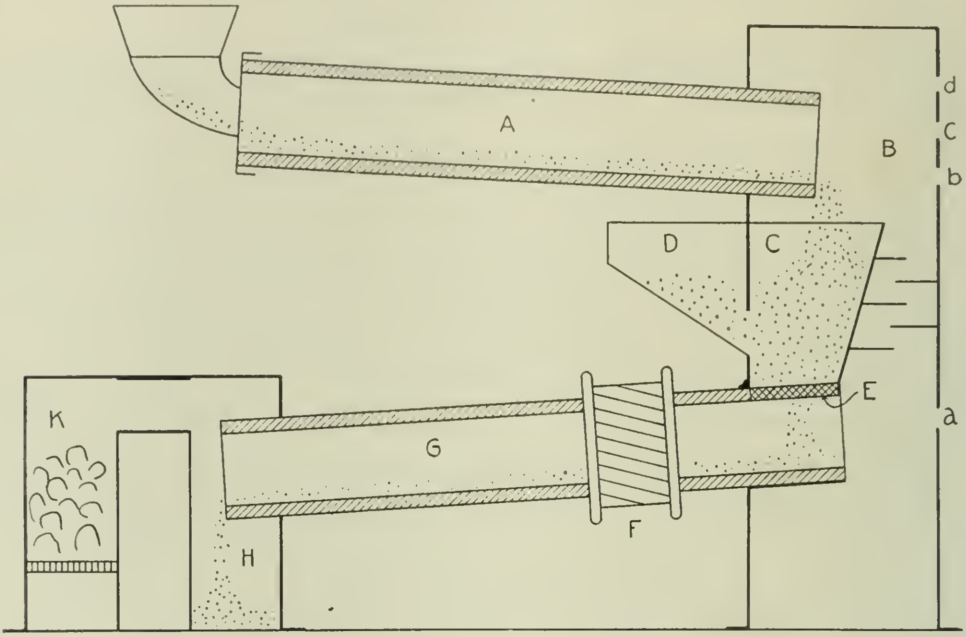
In the Serpek process, aluminium nitride is prepared from bauxite and carbon, the reaction being expressed by the equation:

$$(21)\quad Al_2O_3 + 3C + N_2 = 2AlN + 3CO.$$

Bauxite is mixed with carbon and heated in the presence of nitrogen, combination taking place at about 1550° C. The reaction is hastened by the presence of certain catalytic agents, such as iron, silica, nickel, manganese, titanium oxide, etc. Of these iron and silica are the most active. The reaction is also facilitated by the presence of small quantities of acid gases such as hydrogen chloride and sulphur dioxide. Bauxite can be converted into aluminium nitride at a somewhat lower temperature than pure alumina, owing to the catalytic effect of its impurities. Below 1800° C. the velocity of the reaction is slow, but from 1800° C. to 1850° C. the absorption of nitrogen is very energetic, and in five minutes the alumina is completely converted into nearly chemically pure nitride. Smaller yields are obtained at higher temperatures, and above 2000° C. the formation of nitride practically ceases, owing to decomposition. Recently, Serpek claims to have reduced the time of reaction to a fraction of a second by suitable control of the reaction mixture and the nitrogen supply.

The apparatus employed by Serpek for the manufacture of aluminium nitride is shown diagramatically in Fig. 16. It consists of two superposed rotating cylindrical kilns, slightly inclined to one another and rotating in opposite directions. Each of these kilns is 10 metres long. Into the upper one, A, the powdered bauxite is introduced, which in its descent is calcined and heated to a temperature of 1400° C. by the passage of hot gases over it. On leaving the lower end of the kiln, the calcined bauxite falls into the hopper, C, in the vertical chamber, B, where it is mixed with the proper amount of carbon (coal) introduced at D. The mixture then enters the upper end of the nitriding kiln, G, through the openings, E, and in its descent passes through the electrically heated region, F. Here the mixture is heated to the reaction temperature 1800° C.–1900° C. The kiln, G, is lined with compressed aluminium nitride. The electric resistance furnace, F, is detachable. The electric resistance consists of compressed carbon discs. These are arranged in eight columns each 1.2 metres long, which cross the furnace diametrically and which are connected in series. The resistances are fed by a direct current of 10,000 amperes at 230 volts. Producer gas (about 30 per cent. CO + 70 per cent. N_2), which is formed in the generator, K, enters the lower end of G at a temperature of about 400° C. It passes through the kiln in the direction contrary to that of the descending charge, and in the electrically heated region, F, the nitrogen reacts with the alumina-carbon mixture in accordance with the equation (21). The producer gas, now enriched by the very hot carbon monoxide formed by the reaction, issues from the upper end of the kiln into the vertical chamber, B, preheating the descending charge as it moves along. At *a, b, c* and *d,* it meets with a blast of air which causes the carbon monoxide to burn to carbon dioxide, and the heat produced is employed to calcine and preheat

FIG. 16.



Diagrammatic representation of Serpek apparatus.

the bauxite in the upper kiln. The nitride formed in the electrically heated region, F, is collected in the airtight chamber, H. It contains about 26 per cent. of nitrogen.

FORMATION OF AMMONIA FROM ALUMINIUM NITRIDE.

When aluminium nitride is treated with dilute aqueous alkali, ammonia is produced, the reaction being expressed by the equation:

$$(22) \quad AlN + 3H_2O = Al(OH)_3 + NH_3.$$

The decomposition takes place readily when the nitride is heated with the dilute alkali in an autoclave, with constant agitation, for from two to two and one-half hours under a pressure of two atmospheres, the ammonia being drawn off from time to time. The molecular ratio of sodium hydroxide to aluminium nitride is 1 : 1.5.

In addition to ammonia, a very pure alumina (free from silica and iron) is obtained even from the decomposition of an exceedingly impure nitride made from a low-grade bauxite. While this alumina is not particularly suitable to use over again for the production of more nitride, as owing to the absence of impurities it would require a much higher temperature than is required with bauxite, it is very suitable for the production of metallic aluminium.

ENERGY REQUIREMENTS AND YIELDS.

In the Serpek process there are required, in addition to the heat from coal and producer gas, about 12 kilowatt hours of electrical energy for each kilogram of nitrogen fixed. With a consumption of one kilowatt year, 500 kilograms of nitrogen may be fixed and two tons of by-product alumina produced.

V. ABSORPTION OF NITROGEN AS CYANIDES.

Although it has long been known that cyanide can be formed by heating a mixture of carbon and alkali carbonate in an atmosphere of nitrogen, the development of this reaction for the fixation of atmospheric nitrogen on a commercial scale is due to the work of Bucher, carried out in the United States since the beginning of the war. Although the Bucher process is now working successfully in several small installations, the mechanical difficulties of production on a large scale have still to be solved.

In this process a mixture of soda ash and ground coke, or carbon in any form, is heated in contact with finely divided iron in small retorts to a temperature of from 900° to 950° C. Nitrogen or air is passed through the heated mass, the nitrogen slowly reacting to form sodium cyanide, in accordance with the equation:

$$(23) \quad Na_2CO_3 + 4C + N_2 = 2NaCN + 3CO_2 - 138{,}500 \text{ cal.}$$

The part played by the iron in the reaction is that of a catalyst. The sodium cyanide may either be obtained by distillation of the reaction product, or by lixiviation with hot water.

The sodium cyanide formed in the reaction can be converted readily with air and steam into ammonia as follows: The cyanide is maintained just above its melting point and a current of air passed through the molten mass. It burns to sodium cyanate according to the approximate equation:

$$(24) \quad NaCN + \text{air} = NaCNO + 2N_2.$$

The nitrogen thus formed may be conducted into the cyanide furnaces. The sodium cyanate is then heated with water, which converts it into ammonia long before the boiling point is reached, in accordance with the equation:

$$(25) \quad NaCNO + H_2O = NaHCO_3 + NH_3.$$

The sodium bicarbonate may be used over again in the production of more cyanide.

Unlike other processes for the fixation of atmospheric nitrogen, in this cyanizing process no power factor of any considerable magnitude is involved. Of the raw materials the iron is always recoverable. This also applies to the sodium carbonate, if the final product is ammonia. The raw materials actually expended are, therefore, coke and nitrogen for the cyanizing reaction, steam for the production of ammonia, and coal for furnishing the heat. Bucher has suggested the possibility of employing for fuel the three moles of carbon monoxide formed in the reaction expressed by equation (23), which when burned would yield:

$$(26) \quad 3CO + O_2 = 3CO_2 + 200{,}000 \text{ cal.}$$

The process at the present time involves a large investment and high labor and repair charges, but, as previously mentioned, if the mechanical difficulties are successfully overcome, it appears that nitrogen may be fixed in the form of cyanide more cheaply than by any of the processes already described.

(To be concluded.)

ON THE DETERMINATION OF THE ELECTRICAL AND ACOUSTIC CHARACTERISTICS OF TELEPHONE RECEIVERS.*

BY

LOUIS V. KING, M.A. (Camb.), D.Sc. (McGill), F.R.S.C.,

Associate Professor of Physics, McGill University, Montreal.

I. INTRODUCTION.

Since its invention, in 1877, the telephone receiver as originally developed by Alexander Graham Bell has come into almost universal use.[1] In almost all methods of transmitting intelligence by electrical means, it constitutes the final link whereby electrical energy is converted into acoustic energy and thus made perceptible to the ear as sound. In recent years, with increasing ranges of transmission in telephony and radiotelegraphy, more attention has been directed to the telephone receiver itself as a vital part of the receiving apparatus in its essential function as a detector of extremely small variations of electrical energy. Regarding the telephone receiver as an electrically operated acoustic radiator, it will be evident from results discussed in the sequel that much remains to be done in the matter of its improvement. The writer therefore proposes to discuss briefly the main features of the instrument in its present form with a view to directing attention to points requiring further investigation. No attempt will be made to treat the subject exhaustively in the scope of the present article, as several treatises are now available to readers interested in matters of detail.[2]

II. ELEMENTARY THEORY OF THE TELEPHONE RECEIVER.

In its essential mode of operation, the telephone receiver remains practically the same as when it was first invented. In the bipolar receiver, a thin circular diaphragm of soft iron (japanned or tinned to prevent rusting, about 5.5 cm. in diameter and 0.02 to 0.05 cm. thick) is firmly clamped around its outer edge and usually has its free period of vibration or resonance frequency in the neighborhood of 1000 cycles. The diaphragm is subjected to the pull of a permanent magnet having its poles close to, but not actually touching it; as a result it is distorted to a slightly concave form, as indicated in Fig. 1. Surrounding the poles, and thus interlinked with the magnetic circuit, are wound two coils of silk-insulated or enamelled copper wire, each containing several hundred turns. A small electrical current δi through the coils will result in a variation of the magnetizing force $\delta H \propto \delta i$ acting on the magnetic circuit. If B denotes the average flux density

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* Communicated by the Author.

FIG. 1.

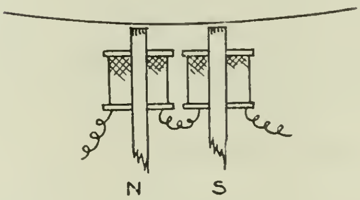
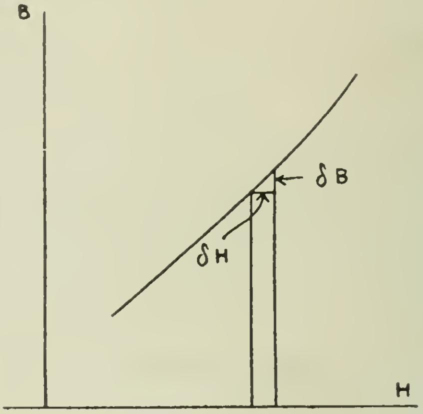


FIG. 2.



in the gap it will be connected with the magnetizing force H due to the permanent magnet by some such curve as that shown in Fig. 2. As H is altered slightly by the field δH set up by the current δi in the coil, it is seen that for small variations $\delta B \propto \delta H$, very approximately,[*] and hence $\delta B \propto \delta i$. If F denotes the total traction on the diaphragm due to the flux B, $F \propto B,^2$ and $\delta F \propto 2B\delta B$, giving, finally, $\delta F \infty 2B.\delta i$. Regarding the diaphragm as a static elastic system, the displacement $\delta x \propto \delta F$, from which it follows that $\delta x \propto 2B.\delta i$; in other words, under these conditions the to-and-fro motion of the diaphragm, giving rise to corresponding sound-waves, follows faithfully the variations of current represented by δi. It will be noticed that the one essential condition for this result is that there exist a constant permanent flux B in the gap as provided for by the permanent magnet.

The assumption involved in the statement $\delta x \propto \delta F$ is legitimate for vibrations of frequencies not too close to resonance, but ignores the dynamics of the diaphragm. Regarding the diaphragm as a vibrating system of one degree of freedom, its motion will be characterized by a differential equation of the type

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[*] In reality the small variations of B and H trace out a minute hysteresis loop detrimental to the exact reproduction of current fluctuations.

$$md^2x/dt^2+kdx/dt+\mu x=F \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

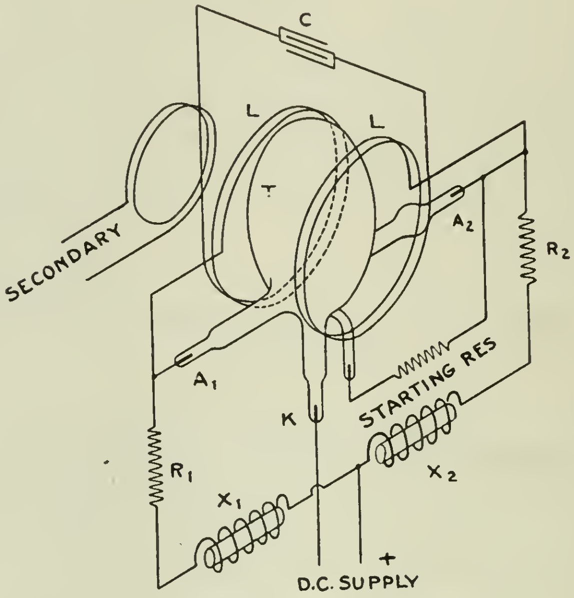
where m is a mass-factor, k a factor representing dissipation of energy due to acoustic radiation, air-friction, eddy-currents, elastic and magnetic hysteresis, etc., and μ a stiffness constant depending on the elastic constants and dimensions of the diaphragm, method of mounting, etc. F represents the traction on the diaphragm resulting from the variation of telephonic current as already explained. A discussion of the consequences of equation (1) would carry us beyond the limits of the present article. It suffices to state that the motion of telephone receiver diaphragms has recently been studied in great detail by Kennelly and his pupils,[3, 4, 6] who describe experimental methods of determining the mechanical constants (m, k, μ) as well as the electrical constants involved in F of equation (1).

III. MEASUREMENT OF THE ELECTRICAL CHARACTERISTICS OF TELEPHONE RECEIVERS.

It is usual to specify a telephone receiver by its direct current resistance. Thus, ordinary telephone receivers vary in D.C. resistance from 25 to 100 ohms, while those employed in radiotelegraphy generally exceed 1000 ohms. Owing to the fact that the coils are interlinked with a magnetic circuit as in an ordinary transformer, it is to be expected that the resistance and inductance of the electrical circuit to an alternating current of pure waveform will depend on the frequency. This dependence is further complicated by the motion of the diaphragm and by the eddy-currents generated in it by its motion in the field of the permanent magnet. Owing to the variable reluctance in the air-gap of the magnetic circuit, the electrical constants will depend on the magnitude of the measuring current, which should be specified directly, or stated in terms of the voltage across the terminals of the receiver.

The actual measurements of the electrical constants of a receiver over the range of telephonic frequencies (100 to 2500 cycles) was until recently a matter of some difficulty owing to the practical impossibility of generating high-frequency alternating currents of pure sine wave form. This difficulty has now been eliminated by the introduction of the "Vreeland Oscillator," an indispensable adjunct to telephone research equipment as a generator of alternating currents of high frequency (300–2500 cycles) and pure wave-form.[5] The essential feature of the apparatus illustrated in Fig. 3 is a capacity-inductance circuit in which electrical oscillations are generated by a mercury-vapor arc deflected alternately between two electrodes from a third by the magnetic field of the coil forming the inductance. The oscillations thus set up are self-perpetuating and may have their frequency adjusted to any desired value by varying the capacity and inductance of the oscillating circuit. A potential between six and twenty volts (on a high-resistance circuit) is obtained across the terminals of a coil closely coupled with that of the oscillating circuit. The purity of the wave-form is stated to be extreme, the most rigid tests having failed to detect any harmonics.

FIG. 3.



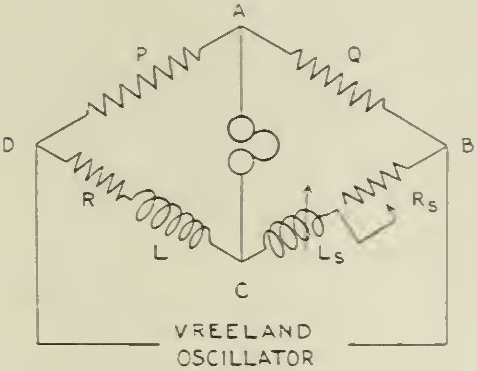
Theoretical diagram of Vreeland oscillator.
(Reproduced with the kind permission of the Vreeland Apparatus Company, New York.)

Such a source of alternating E. M. F. is especially well adapted to the measurement of inductance and resistance of telephone receivers by the Rayleigh bridge. The arrangement shown in

Fig. 4 has been found to be most convenient for the purpose. P and Q are two non-inductive resistances, preferably adjusted to equality. The coil to be measured, having resistance R and inductance L, is inserted in the third arm of the bridge while (L_s, R_s) represent a variable resistance and inductance inserted in the fourth arm. This is best provided for by a non-inductive resistance box connected in series with some form of continuously adjustable inductance such as the Ayrton-Perry Inductometer.

The alternating potential is applied across BD, while a sensitive receiver is connected across AC. The inductance is first adjusted until minimum current passes through the telephone and the resistance then varied until the current is still further reduced.

FIG. 4.



Finally, after a series of successive settings of L_s and R_s, a very close approach to dead silence may be obtained in the telephone. As zero current in this part of the network implies equality of voltage and synchronism of phase at A and C, the condition for a balance is

$$R/R_s = L/L_s = P/Q \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (2)$$

The electrical characteristics of telephone receivers as measured in this way have been studied in great detail by Kennelly and his co-workers.[6] The results of a series of observations carried out in this way on a Bell bipolar receiver of 87 ohms D. C. resistance are shown graphically in Fig. 5. If I be the r. m. s. value of the alternating current and R the effective resistanc at a given frequency, the electrical input is I^2R watts. If R_0 be the direct-current resistance, the corresponding copper loss is I^2R_0 watts. It may be mentioned in passing that the extent to which the A. C. resistance differs from the D. C. resistance is a measure of internal energy losses and often serves as a rough indication of the relative merits of different types of telephone receivers.

IV. NOTE ON THE PRECISION MEASUREMENT OF FREQUENCY.

In telephonic researches the exact measurement of frequency is of great importance, especially in studying the characteristics near resonance. A very satisfactory precision sonometer was devised by the writer for the purpose and is shown diagramatically in Fig. 6. One extremity of a fine steel wire (1.373 grammes per metre) about a metre long was fastened at *A*, the upper end of a vertical cathetometer scale. The reading telescope was removed from the sliding support and replaced by a sharp bevel edge *C* about 4 cm. wide, constructed of brass. The same support carried a telephone magnet *T* mounted in such a way as to allow of vertical and horizontal adjustment. The lower extremity *B* of the wire was firmly soldered into a short perforated copper plug (2 mm. diameter × 5 mm.) which could be screwed into the centre

FIG. 5.

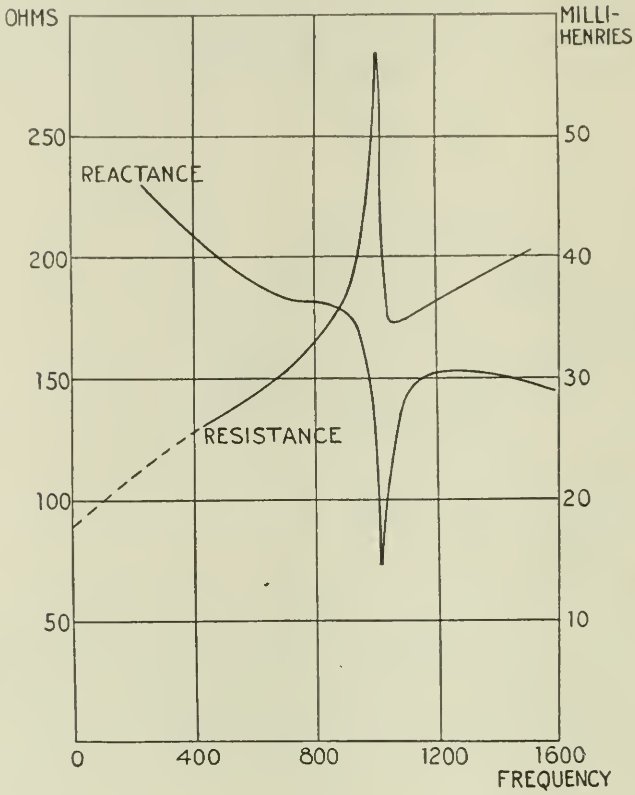
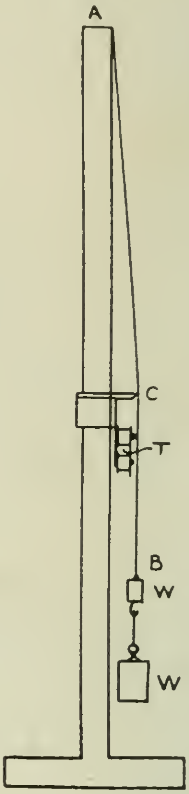


FIG. 6.



of the upper end of a cylindrical weight w (188.2 grammes) carrying a hook in the centre of its lower end as shown in the figure. To this hook could be attached a series of weights W (in practice a kilogramme weight was used). The coils of the telephone magnet were connected through suitable resistances across the alternating e. m. f., and the movable bevel-edge adjusted up and down until the wire BC was set into vibration. The inertia of the mass w was so great that the lower end B of the wire could be considered fixed for vibrations over the range of telephonic frequencies. The length could be accurately read off on the cathetometer scale by means of the vernier, the zero having been determined by bringing the bevel edge into coincidence with B, the upper surface of the copper plug into which the wire was inserted. Care was taken to leave the wire under full tension in the determination of the zero to allow for elastic stretching which was noticeable, as the wire was stressed to a degree not far from the elastic limit to obtain as great a length l as possible corresponding to a given frequency, given by the well-known formula

$$f=\frac{1}{2l}\sqrt{\frac{T}{m}} \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

where T is the tension in dynes and m the mass of the wire per unit length. As long as the vibrating portion remained less than 50 cm. in length, it was easily shown by calculation that variations in that of the upper inclined portion of the wire did not affect the value as read off on the cathetometer scale to one part in a thousand.

Owing to this particular method of mounting the vibrating wire the length and tension were extremely determinate while dissipative forces were reduced to a minimum, with the result that the resonance was correspondingly sharp. It was found that the maximum resonance could be visibly altered by a variation of 1/10 mm. in a length of 30 cm. or by an alteration of 2 grammes in a tension of 1 kilogramme. In the course of the writer's researches the instrument just described was found to be extremely convenient in frequency determinations over a range varying from 360 to 1600, with an accuracy represented by an error less than one part in a thousand.

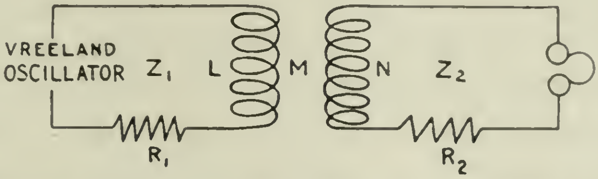
V. MEASUREMENT OF THE AUDIBILITY CHARACTERISTICS OF TELEPHONE RECEIVERS.

Determination of Audibility Current and Voltage.—In many applications it is important to know the sensitiveness of a telephone receiver. This may be defined as the minimum electric energy required to give an audible sound. The current required to give a just audible sound is referred to as the *audibility current,* while the voltage across the terminals is similarly referred to as the *audibility voltage.* It is to be expected that these characteristics will depend on several factors other than the design of the receiver, such as the sensitiveness of hearing of the observer, type of signal under consideration, existence and nature of extraneous sounds, etc. As far as possible a telephone receiver should be tested by an observer under the same conditions as those in which he will use the instrument in practice. As a receiver must in the last analysis serve to detect electrical currents by its effect on the ear, it is evident that an audibility test is the final measure of the effectiveness of the instrument for this purpose.

Several methods of testing telephone receivers have been described by various writers.[7, 8, 9] For details of the experimental arrangements, the reader is referred to the original papers. One of the methods most commonly used involves shunting the receiver by a non-inductive resistance until the telephonic current is so far reduced that the sound is rendered just audible. It is assumed that the current through the receiver may be calculated by the usual formulæ for inductive currents, the effective resistance and inductance having been determined by some such method as that described above. In view of the high frequencies involved, special precautions must be employed in ascertaining that all the resistance-boxes are of negligible inductance. According to Lord Rayleigh,[7] resistance boxes of more than 10,000 ohms should not be employed, owing to the capacity effect of the insulation. Even if these conditions are satisfied, a further element of uncertainty exists, owing to the fact that the effective resistance and self-induction of the receiver are measured for currents of a few milliamperes and may differ considerably from the values corresponding to the audibility current—a possibility first pointed out by Austin.[9] Further difficulties are met with in eliminating the direct inductive effect of the alternating current in the various circuits on the coils and diaphragm of the receiver itself, a source of trouble which is all the more difficult to eliminate as the receiver is more sensitive.

A simple method of determining the audibility characteristics of receivers was devised by the writer in the course of telephonic researches, in which the above-mentioned difficulties are almost entirely eliminated. The circuit is shown diagrammatically in Fig. 7. A primary circuit of self-induction L, resistance R_1, and impedance Z_1, is connected across the terminals of the Vreeland oscillator, whose voltage V is measured by an electrostatic voltmeter. The telephone receiver is connected to form part of a secondary circuit of self-induction N, resistance R_2, and impedance Z_2, loosely coupled with the primary, so that M is small compared to L or N.

FIG. 7.



Audibility Voltage.—The telephone receiver is connected directly across the secondary, whose resistance and self-induction are both made small compared to that of the receiver itself. A non-inductive resistance R_1 of the order of a megohm * is inserted in the primary circuit, so that $Z_1 = R_1$ very approximately. If x be the current in the primary, the voltage across the terminals of the receiver is $e = 2\pi f.M.x$ very approximately, while $x = V/Z_1 = V/R_1$ very nearly. Hence we obtain

$$e = 2\pi f M V/R_1 \quad \ldots \ldots \quad (4)$$

In practice it is convenient to vary the mutual inductance until the sound in the receiver is just audible, when the audibility voltage may be obtained from (4) independently of the electrical characteristics of the receiver, if M is known experimentally or determined by calculation. In the writer's researches two coaxial coils were used, the primary of 341 turns having a resistance of 1.28 ohms, self-induction .0317 henry and mean radius 10.7 cm. The secondary consisted of a small coil (300 turns, 17.4 ohms resistance, .013 henry self-induction, 3.9 cm. mean radius) arranged to slide along a central rod so that the mutual induction with respect to the primary varied from 2.6×10^{-3} henry to 0.1×10^{-3} henry at 35 cm. distance between the coils. From a calibration curve, M could easily be read off in terms of the distance between the coils. To avoid direct inductive effects, it was found necessary to set up the testing apparatus at a considerable distance from the Vreeland oscillator (about 25 feet) and to bring the current to the primary through a twin wire cable enclosed in a grounded lead sheath.

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* The resistance of a graphite pencil-mark along a groove cut into an ebonite slab is suitable for the purpose, as having negligible self-induction and capacity.

Audibility Current.—In view of the fact already mentioned that the effective impedance of a telephone receiver depends on the value of the measuring current and is uncertain (and probably not determinable) for audibility currents, it is unsafe to determine the latter from the audibility voltage. The audibility current may be determined independently of the electrical characteristics by a slight modification of the above apparatus. The current in the primary is given by $x = V/Z_1$, while the current in the secondary is given by $i = 2\pi fMx/Z_2$. A high non-inductive resistance R_2 of the order of a megohm * is inserted in the secondary, so that $Z_2 = R_2$ very approximately, and in these circumstances

$$i=\frac{2\pi fM}{R_2}\,\frac{V}{Z_1} \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (5)$$

a relation in which the impedance of the telephone receiver does not enter as long as it remains of the order of a few thousand ohms. As before, M is altered until the limit of audibility is reached. In this case it may be necessary to make x fairly large to get an appreciable current in the high-resistance secondary. To avoid the direct inductive action on the receiver it is advisable to connect it through grounded metal-sheathed cable and determine audibility at a considerable distance from the primary coil.

The electrical and audibility characteristics of a typical wireless telephone receiver tested by the writer is given as follows:

D. C. resistance of two receivers of head-piece in series 2900 ohms.
At 1020 cycles:
Effective resistance .... 4970 ohms } measuring current
Effective inductance ....0.890 henry } 0.79×10^{-3} amperes.
Audibility voltage ......9.0×10^{-6} volts
At 500 cycles:
Effective resistance .... 4210 ohms } measuring current
Effective inductance ....1.140 henry } 0.95×10^{-3} amperes.
Audibility voltage .....38.0×10^{-6} volts

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* The resistance of a graphite pencil-mark along a groove cut into an ebonite slab is suitable for the purpose, as having negligible self-induction and capacity.

VI. ON THE ACOUSTIC OUTPUT AND EFFICIENCY OF TELEPHONE RECEIVERS.

Although it was pointed out many years ago by Abraham[10] that the acoustic efficiency of the usual type of telephone receivers was *at most* 1/700, little success seems to have been made in remedying the poor acoustic performance of these instruments. The ability of the telephone receiver to detect very small variations of electrical energy is due more to the extreme sensitiveness of the ear as an organ of perception than to any inherent excellence of mechanical or electrical construction.

The amplitude of motion of a telephone diaphragm for an easily audible sound is of the order 10^{-3} to 10^{-4} centimetre. The detailed study of diaphragm vibrations recently carried out by Kennelly and his collaborators has furnished the writer of this article with material for calculating the acoustic output and efficiency of the corresponding telephone receivers. In a theoretical investigation by the writer, which it is hoped to publish shortly, the acoustic radiation from a vibrating diaphragm is calculated on the basis of Lord Rayleigh's theory.[11] The diaphragm is supposed to vibrate so that every part of its surface is oscillating in the same phase, an assumption which is legitimate as long as no natural overtones are excited. If W is the amplitude of motion of any point of the diaphragm, the *volume-displacement* is defined by

$$V = \int W dS \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (6)$$

V represents the volume included between the equilibrium and extreme positions of the diaphragm. Provided the wave-length is large compared to the dimensions of the diaphragm, the energy radiated per second in a large open space is given by

$$[dw/dt] = \frac{1}{8} \frac{\rho_0 \pi^4 V^2}{\pi c} \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (7)$$

where ρ_0 is the density of the medium, f is the frequency, $n = 2\pi f$, while c is the velocity of sound in the medium.

In a paper by Kennelly and Taylor,[4] explorations over the surface of a vibrating telephone receiver were carried out and the corresponding current was measured. For the details of the measurements reference must be made to the original paper. In particular a curve is given from which the mean amplitude at various radial distances may be obtained in the case of a bi-pole, 87 ohm, Bell telephone receiver vibrating without the cap over the diaphragm. The vibration contours were obtained at resonance frequency, $f = 992$ cycles, and show marked lack of symmetry owing to the magnetic tractions being applied over the two poles. A rough calculation by quadratures gave for the volume-displacement $V = 3.8 \times 10^{-3}$ cm.^{3} Writing $\rho_0 = .00129$ and $c = 3.3 \times 10^4$ cm./sec. for air at ordinary temperature and pressure, we obtain

$$[dw/dt] = 34.2 \text{ ergs/sec} \quad \ldots\ldots\ldots\ldots \quad (8)$$

Unfortunately the effective resistance of the receiver in question was not given, but the value at resonance for one of practically identical construction is quoted as $R' = 225$ ohms. The current $I = .00202$ amperes. Hence

$$(\text{electrical input}) = I^2R' = 9120 \times 10^{-7} \text{ watts} = 9120 \text{ ergs/sec} \quad \ldots\ldots \quad (9)$$

Comparing (8) and (9) we obtain for a rough estimate of the acoustic efficiency *at resonance* the ratio

$$\eta = .00375 \quad \ldots\ldots\ldots\ldots \quad (10)$$

It is to be expected that the acoustic efficiencies at frequencies far removed from resonance will be very much less than the above value. In Table I of a paper by Kennelly and Affel [3] are given the effective resistances R' and maximum displacements $|x|$ at the centre of a receiver diaphragm (with cap in position) for various frequencies between 429 and 1137 cycles at constant current $I = .00204$ ampere. As the volume-displacements are proportional to $|x|$ (assuming geometrically similar vibration contours over the frequency range) and the electrical power-input at constant current is proportional to the effective resistance R', it follows from (7) and (9) that the ratio of the efficiency at a given frequency to that at resonance is given by the expression

$$\frac{\eta}{\eta_r} = \frac{f^4 |x|^2 R'_r}{f^4_r |x_r|^2 R'} \quad \ldots\ldots\ldots\ldots \quad (11)$$

where the suffix $_r$ refers to resonance conditions. Quoting a few values from Table I of the paper by Kennelly and Affel,[4] we derive the following:

TABLE I.

Frequency cycles/sec.	R' ohms	$\lvert x \rvert$ cm.	$\frac{\eta}{\eta_r}$	Remarks
429	130	1.8×10^{-4}	.0016	
70.	153	1.6	.0075	
804	166	1.9	.0175	Current I = .00204 r. m. s. amperes throughout.
923	193	2.85	.0580	
987	254	6.03	.256	
1020.4	224	10.45	1.000	Resonance frequency 1020.4.
1043	151	7.60	.857	
1137	159	0.95	.018	

Keeping in mind that the resonance efficiency as already deduced is in the neighborhood of 4/1000, it will be deduced from the above table that the efficiency over the ordinary range of frequencies is extremely low, amounting to only a few parts in a hundred thousand or a million.

It is thus evident that the telephone receiver, considered as a means for transforming electrical energy into acoustic output, is an extremely inefficient instrument. It remains for future research to determine the location of the energy-losses and to remove their cause if possible. According to some experiments by the writer, it appears that magnetic hysteresis losses are chiefly contributory. The depth of penetration of flux variations into the permanent magnet due to high frequency telephonic currents in the coils is very small, amounting perhaps to a tenth or hundredth of a millimetre. Unfortunately it is this flux variation which is effective in causing the diaphragm to vibrate, and only a moderate degree of improvement can be obtained by reducing eddy-currents by lamination. The losses just referred to may be reduced to some extent by welding to the permanent magnet spool cores of low-hysteresis iron (such as silicon steel or vacuum-distilled iron). Unavoidable hysteresis and eddy-current losses are, however, set up by the vibration of the diaphragm in the strong magnetic field due to the permanent magnets.

In a recent paper by Kennelly and Nukiyama,[12] it is estimated that in the particular telephone receiver whose constants are quoted in Table I above, forty per cent. of the electrical input is delivered at resonance to the diaphragm as mechanical output, including internal frictions and acoustic delivery. The estimate of acoustic efficiency at resonance calculated in the present paper (0.375 per cent.) shows that only about one per cent. of the mechanical power delivered to the diaphragm is converted into sound, the remainder being dissipated as heat by the action of elastic hysteresis, internal air-friction and eddy-motion, frictional losses at the clamped boundary, etc. The problem of designing diaphragms to reduce these losses to a minimum constitutes in the writer's opinion a most important field of research connected with improvements in the acoustic efficiencies of telephone receivers.

For the intelligible transmission of speech the telephone receiver must respond without too great variation in loudness to a wide range of frequencies; or, in other words, resonance must not be too sharp. This requires a high degree of damping, involving large energy-losses and inevitable low efficiency.

The case is otherwise when it is required to detect small alternating currents. As far as possible dissipative forces should be reduced to a minimum and the receiver should be designed to operate at the resonance frequency of the diaphragm. The less the energy-losses and the greater the sensitiveness of the instrument and the sharper is the resonance of the diaphragm.

The recent trend of radiotelegraphy in the matter of power economy and long distance transmission has led to a demand for increased sensitiveness in the receiving apparatus. This has been met by the introduction of current amplifiers of various types, giving magnification amounting in some instances to a hundredfold or more. The telephone receiver is, however, an essential part of the receiving apparatus and any marked improvements in its construction leading to higher acoustic efficiencies are greatly to be desired. In the reception of radio-telegraphic signals involving the detection of periodic fluctuations of current considerable gain in sensitiveness may be obtained by employing a receiver whose diaphragm is tuned to resonance with the frequency of the telephonic current. In a sensitive receiver in which energy-losses are reduced to a minimum, the resonance will be fairly sharp. In order to meet unavoidable variations of spark frequency occurring in practice, a receiver having a diaphragm capable of continuous tuning over a considerable range of frequencies would enable it to be always employed at maximum sensitiveness, an advantage which will be realized from an inspection of Table I, in which a change of frequency from resonance at 1020 to 987 cycles is shown to result in the reduction of efficiency to one-fourth of the maximum value.

It is hoped that the present article will serve to direct attention to the need for further research directed towards the improvement, in regard to acoustic efficiency, of existing forms of telephone receivers, in view of their almost universal use in radio-telegraphy and other forms of signalling across space.

VII. REFERENCES.

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[10] ABRAHAM, H.: "Rendement Acoustique du Téléphone," *Comptes Rendus,* T. 144, 1907.

[11] RAYLEIGH: "Sound," 1896, Vol. ii, Art. 302.

[12] KENNELLY, A. E., and NUKIYAMA, H.: "Electromagnetic Theory of the Telephone Receiver," *Proc. American Institute of Electrical Engineers,* Vol. xxxviii, April, 1919, pp. 491–539. Extensive references are made in this paper to the most recent researches on telephone receivers.

Production of Smoke Screens in Warfare. G. A. RICHTER. (*Proceedings of the American Electrochemical Society,* April 3–5, 1919.)—When smokes were first demanded by the fighting forces of the Army and Navy, the ordnance deparments furnished quantities of phosphorous for that purpose. It was soon realized that other more avialable smoke mixtures must be developed to meet the demands. Early work had indicated that hydrochloric acid gas when reacting with ammonia vapors could under certain conditions produce a smoke having satisfactory obscuring power. The difficulty of handling large quantities of hydrochloric acid as such made it necessary to employ other means.

Advantage is taken of the property of both the silicon and titanium tetrachlorides to hydrolyze readily, forming hydrochloric acid and a residum of the corresponding oxide or hydroxide. The speed of such hydrolysis can be controlled. It is a well-known fact that a quantity of the titanium chloride left exposed to the action of moist air will fume for several hours, the time depending on the surface exposed and the humidity of the atmosphere. If the same amount of the tetrachloride is suddenly dispersed by means of an explosive charge, there results a much larger cloud for a correspondingly shorter period. The same is true of silicon tetrachloride, although the cloud produced is of less intensity. In the presence of ammonia, the clouds obtained with both the tetrachlorides are intensified even more, due to the formation of ammonium chloride.

In order to obtain the greatest total obscuring power, the following conditions are necessary: (1) The liquid ammonia and the silicon tetrachloride must be sprayed into the atmosphere in a finely atomized state. (2) The smoke apparatus must allow a great dilution of both ingredients with air before they are allowed to mix. (3) There should be sufficient moisture in the air to allow a complete hydrolysis of the silicon tetrachloride before the vapors come in contact with the ammonia vapors. The Navy Smoke Funnel and the smoke knapsack, devised for trench warfare, are both designed to conform to these conditions. The ammonium-titanium tetrachloride under laboratory conditions gives better results than the silicon compound, but its slowness of evaporation causes gumming of the nozzels. It was never used in the smoke funnel manufactured for the American Navy.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

THE VISCOSITY OF GASOLINE.[1]

[ABSTRACT.]

THE short tube viscosimeters which are in ordinary use for determining the viscosity of lubricating oils cannot be used with gasoline, for which it is necessary to employ an instrument with a much longer outlet tube. The Ubbelohde viscosimeter, primarily designed for kerosenes, appeared suited to the purpose and two instruments of this type were used in determining the relation between time of discharge and viscosity in poises. By a large number of runs with water and ethyl alcohol solutions, liquids of known viscosity, it was found that:

$$\text{Kinematic viscosity} = \frac{\text{viscosity in poises}}{\text{density, } g \text{ per cc}} = .0000887\,t - \frac{1.438}{T}$$

where t is the time of discharge in seconds. The published standard dimensions of the instrument give .125 centimetre as the inside diameter of the outlet tube, but this was found to be .129 in the instruments tested. The time of discharge for 100 cubic centimetres of water at 20° C. (68° F.) was found to be very close to the specified value of 200 seconds. It is therefore suggested that 200 seconds should be retained as standard, but that the diameter of the outlet tube should be changed to .129 centimetre.

In dealing with highly fluid liquids such as gasoline, it is convenient to use the fluidity or reciprocal of the viscosity in poises in place of the viscosity. The temperature-fluidity curve is very much more nearly a straight line than is the temperature-viscosity curve. Fluidities were found for thirteen samples of gasoline and one kerosene over a temperature range from 5° to 55° C. (41° to 131° F.). These tests showed that kerosenes have a lower fluidity or higher viscosity than water, while gasolines, though varying greatly among themselves, are all more fluid than water. This is in agreement with the published data in regard to kerosene; the available information in regard to the viscosity of gasolines is very meagre.

It is generally recognized that the gravity test is an uncertain guide to the quality of kerosene or gasoline, if taken by itself without information as to the source of crude oil. This was confirmed by the tests on gasolines, their order when arranged according to densities being quite different than when arranged according to fluidities. A fractional distillation is often used as a substitute or supplement to the gravity test, and this gives valuable information. It requires, however, more complicated apparatus and greater skill than needed to test fluidity. Furthermore, the close relation between fluidity and vapor pressure, which has been pointed out by Bingham [2] points to the conclusion that fluidity may be an extremely good criterion for volatility.

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* Communicated by the Director.

[1] Technologic Papers, No. 125.

Bingham gives tables of fluidities of various pure chemical compounds over a wide range of temperatures, and these tables were used to compare the fluidities of the thirteen gasolines with those of the aliphatic hydrocarbons. It was found that ordinary commercial gasoline, as now sold for use in automobiles, has a fluidity slightly less than octane. Most of the special gasolines, intended for use in airplane motors, have a fluidity between that of heptane and hexane. The temperature-fluidity curves of these gasolines were nearly straight and parallel, so that the order of the different gasolines, arranged according to fluidity, would be nearly independent of the temperature considered. It is suggested that the specification of the fluidity at two temperatures might serve to define a desired grade of gasoline.

THE CONSTITUTION AND MICROSTRUCTURE OF SILICA BRICK AND CHANGES INVOLVED THROUGH REPEATED BURNINGS AT HIGH TEMPERATURES.[3]

By H. Insley.

[ABSTRACT.]

WITH the coöperation of many of the principal American manufacturers of silica brick, petrographic microscopic studies were made of the raw quartzite, the finished brick, and brick which had received repeated burns by actual use in kilns, coke ovens, etc., for the purpose of determining the original constitution, and also components of silica brick stable under conditions of repeated burning such as it would undergo in the industries. Test cubes were also prepared in the laboratory of the Bureau of Standards according to a standard commercial mix and burned at 50° intervals from 1200°–1500° C. in order to trace out the mineralogical and structural changes with increasing temperature.

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[2] E. C. Bingham, *Am. Chem. Jour.*, Vol. 43, p. 296, 1910.

[3] Technologic Papers, No. 124.

Quartz, cristobalite, tridymite, pseudo-wollastonite (α–CaO.-SiO_2), and glass are found to be present in silica brick. Pseudo-wollastonite and glass are never present in anything but small amounts. The proportions of the other constituents vary according to the heat treatment undergone.

Microscopical quantitative analyses of the relative proportions of the three predominant minerals were made of each brick examined. These analyses show that the longer a brick is burned at high temperatures but below 1470° C., the greater will be the amount of tridymite present.

Silica brick are usually found to have a porphyritic-like structure made up of phonocrysts and groundmass. This structure is not due to any chemical or physical action which takes place during the heating or cooling of the brick but is caused by the method of grinding the raw material, the phonocrysts being the coarsely ground pieces while the groundmass is made up of finely ground material and rock flour.

Microscopic examination shows that the first inversion is from quartz to cristobalite and begins in the groundmass. The material which is broken up in the phonocrysts by shattering due to expansion on heating is then transformed into cristobalite and rims of cristobalite form around the phonocrysts similar in appearance to the reaction rims seen around minerals in natural rocks. After longer heating tridymite begins to appear in the groundmass. The crystals are at first very small and rather poorly developed but increase in size with successive reburnings. Tridymite is usually present as wedge-shaped and more complicated interpenetration twins. In reburned brick the quartz phonocrysts are occasionally entirely transformed to cristobalite and sometimes even tridymite crystallites begin to appear in the phonocrysts.

The lime added in the grinding of the raw materials does not appear to aid in the bonding of the brick by the compounds which it forms but rather by hastening the inversion of the silica through its fluxing action. Most of the bonding action seems to be due to the interlocking of the cristobalite and tridymite crystals. Any glass present aids but little in the bonding.

Permanent expansion is caused by the inversion of quartz to cristobalite and tridymite. A large proportion of tridymite is desirable in silica brick since it has the larger permanent expansion and subsequent buckling of the furnace walls is reduced to a minimum.

The investigation has verified the prediction of Fenner: that with a comparatively small amount of flux quartz inverts to cristchalite, then to tridymite at temperatures where cristobalite is the unstable and tridymite is the stable modification. In the case of every brick examined cristobalite was the first inversion product to form whether the conditions had been such as to promote much or little inversion. Moreover, the final inversion product reached after many reburnings to the temperature range where it was the stable modification, resulted invariably in the formation of tridymite.

THE ULTRA-VIOLET AND VISIBLE TRANSMISSION OF EYE-PROTECTIVE GLASSES.[4]

By K. S. Gibson and H. J. McNicholas.

Many glasses are on the market and extensively advertised to protect the eyes from injurious radiant energy. Unfortunately, but little authoritative information concerning the properties of these glasses has been available. The public and even oculists and physicians have had little to guide them in selecting such glasses except the claims of makers and agents. One purpose of such glasses is to absorb the injurious radiant energy which is emitted along with the light from certain lamps as well as from welding arcs and industrial furnaces, while transmitting sufficient light for vision. They thus act as filters. Another purpose in certain cases may be to absorb part of the light so as to reduce a blinding brilliance. Glasses of different types are required for different needs. The degree to which these glasses actually fulfill their avowed purpose can only be determined by measurements of their "transmission" (*i.e.,* the ratio of transmitted energy to the energy falling on them) for the various forms of radiant energy in question. The Bureau of Standards has made such measurements on a great number of glasses now on the American market and the results are published in this paper.

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[4] Technologic Papers, No. 119.

PHYSICAL AND CHEMICAL TESTS ON THE COMMERCIAL MARBLES OF THE UNITED STATES.[5]

By D. W. Kessler.

[ABSTRACT.]

THIS paper is the first report of the Bureau of Standards in connection with an extensive coöperative program for investigating the building stones of the United States. The other government departments participating in the work on different phases of this investigation are the U. S. Geological Survey, Bureau of Mines and Office of Public Roads.

This paper comprises the results of strength tests, water absorption, porosity, specific gravity, freezing, thermal expansion, electrical conductivity and chemical tests on fifty-two different types of marbles produced in this country. The purpose of the work is to determine the relative value of the different types for building purposes, and other special uses.

Compressive strength tests were made on specimens in the original condition and on specimens after being soaked in water for two weeks. The strength of the dry specimens gave values ranging from 7850 to 50,205 pounds per square inch. As a rule the soaked specimens gave lower compressive strengths than the dry, and in a few cases the loss due to soaking was over 25 per cent.

Transverse and tensile strength tests are included and show the strength of the specimens when broken perpendicular and parallel to the bedding planes.

The freezing tests made for this report consisted in determining the loss in weight and strength due to thirty freezings and thawings. While these losses were considerable in most cases, some samples showed practically no loss and occasionally a gain in strength was indicated. Hence it was decided that thirty freezings are not enough to give a trustworthy indication of the durability of such materials. An apparatus has been installed which automatically shifts the specimens back and forth between a cold chamber and warm chamber at certain intervals. With the use of this apparatus, it is possible to make a great number of freezings which will correspond to several years of exposure to the weather. It is proposed to make extensive weathering tests with this apparatus to determine more definitely the relative effect of frost action on the different marbles as well as other types of building stones.

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[5] Technologic Papers, No. 123.

Electrical resistivity tests were made on a number of different types to determine their relative value as insulators and resistivity under different conditions of moisture. The results show a considerable range of values, indicating that there is a choice of marble for use in switchboards and allied purposes.

Measurements of the thermal expansion made on a few samples of marble in this investigation show that this material does not expand at a uniform rate even at ordinary temperatures. As the temperature is increased the rate of expansion increases, hence it is not possible to state a coefficient of expansion for marble that will hold good for any very great range of temperatures. Another peculiarity brought out by these tests was the fact that marble when expanded by heating does not contract to its original dimensions as the temperature is lowered, but retains a part of the increase permanently. A number of successive heatings show the same effect, each adding an increment of length to the specimen.

A few cases of warped marble slabs are illustrated and a discussion is made of the causes which may be instrumental in bringing about this warping.

Casein Waterproof Glue. H. A. Gardner. (*Aircraft Technical Note No. 46,* Navy Department, Bureau of Construction and Repair, May 23, 1918.)—The Forest Service has recently completed some very extensive tests with casein glue. These tests have demonstrated that there are now available, commercially at least, three brands which are all furnished by the makers in the form of dry compounds to be mixed with water. These glues are to be considered waterproof in the sense that they are not dissolved out or injured by water. Permanently prolonged soaking causes such glues to soften and become weak, but upon subsequent redrying they regain their former strength. The principal difficulty with these glues is in their rapidity of setting after being mixed with water; from two to five hours is the longest period of fluidity. Experimental batches of casein glue, to which certain materials have been added to delay the set, have, however, remained fluid and workable for periods as long as forty-eight hours.

Attempts have been made to determine what percentage of bad joints would occur in using casein glue. Every one of about 200 specimens made by ordinary mechanics was found satisfactory. It is believed that, if the instructions of the manufacturers are followed, casein glue is a safer material for aircraft construction than hide glue. It appears, therefore, for strength members in aeroplanes, that these glues should be used in place of hide glue.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

A NEW YELLOW DYE AND LIGHT—FILTERS MADE FROM IT.[1]

By C. E. K. Mees and H. T. Clarke.

[ABSTRACT.]

THE dyes previously used for making light filters were principally Picric acid, Tartrazine and Filter Yellow. Picric acid, while having a satisfactory absorption, is unstable and as a consequence the early gelatine filters were made chiefly with Tartrazine, which is quite stable. Tartrazine, however, has the disadvantage that it transmits the ultra-violet and that filters made from it are relatively inefficient.

The introduction of Filter Yellow in 1907 supplied a dye having a good absorption in the ultra-violet, reasonably sharp cut in the spectrum and great stability. It was still desirable for high efficiency, especially in filters for aerial photography, that a dye should be obtained possessing the stability and ultra-violet absorption of Filter Yellow but with greater sharpness of cut.

The compounds of phenyl hydrazine with sugars are yellow in color and a soluble compound of this type has been prepared by coupling glucose with parahydrazine-benzoic acid. The sodium salt of glucose-phenyl-osazone-para-carboxylic acid prepared in this way, proving to be a very suitable dye for the preparation of sharp cut light filters, has been given the name of "Eastman Yellow."

From this new dye light filters have been prepared under the designation of EK-1 and EK-2 filters, which are stable to light, have a very strong absorption for ultra-violet, and are considerably sharper and more efficient than K filters made from Filter Yellow.

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* Communicated by the Director.

[1] Communication No. 75 from the Research Laboratory of the Eastman Kodak Company, published in *British Journ. Photog.*, 1919, p. 48, and *Journ. Ind. and Eng. Chem.*, current issue.

Concrete Freight Car. ANON. (*Communication from the Portland Cement Association,* March, 1919.)—New uses for concrete come frequently to public notice. One of the latest, and one that promises to be far-reaching, is the concrete freight car. The beginning of practical plans for the manufacture of reinforced concrete freight cars dates from 1909 when a patent for such a car was granted to Joseph B. Strauss, of Chicago. On account of the war, construction of a trial car was delayed, and it was but recently that the first car, of the gondola type, was completed by the R. F. Conway Co., Chicago, and tested under service conditions. Not only in the material used, but in its design and the details of construction, it represents an interesting departure from usual methods.

The basic feature of the design is a steel skeleton body forming the outer boundary of the car, and mounted upon a steel underframe. The concrete walls and floor are contained within this frame and, together with the frame and floor reinforcement, are connected to, and interlocked with, the underframe. The steel frame forms the finishing and protecting edges, thus entirely shielding the concrete and also serving as a complete system of stress-bearing members. In the construction of the test car, the "cement gun" was used. The forms were placed on the outside of the car, and the cement was shot against them from within. The outside of the car, that is, the surface against the forms, was given a smooth finish, but the interior was left much as it came from the gun.

Tests of the completed car, both empty and loaded, demonstrated its practicability for rough service. In the test without load it withstood extremely rough handling in switching, and came through without injury. Subsequently, the car was loaded with fifty-five tons (10 per cent. overload) of sand and turned over to a switching crew for service handling. It withstood this test also without injury. Other merits are claimed for the concrete car. It will not need painting and will practically eliminate maintenance charges. Its life will be much longer than that of the wooden car. It will have the important advantage, also, of being unaffected by its cargo, and will consequently be adapted better than the steel car for hauling slag and ashes.

Plans are already under way for the quantity manufacture of these cars. The fact that the first one was built with the sanction and coöperation of the United States Railroad Administration, and that the Illinois Central Railroad took an active interest in its construction and test, indicates that extensive production will not be long delayed.

NOTES FROM THE RESEARCH LABORATORY, GENERAL ELECTRIC COMPANY.*

THE MECHANISM OF FRACTURE IN STEEL.

By W. E. Ruder.

[ABSTRACT.]

Microscopic examination shows that steel is crystalline in nature and heterogeneous in composition. Each constituent has its own physical and chemical characteristics, and the results which we get from the test bar are really summations of the physical characteristics of the constituents. Alternating stress is one of the most accurate methods for the determination of the true elastic limit.

The photograph illustrates very satisfactorily the difference in strength and the manner of fracture between large single crystals of the same steel which differ only in orientations. Crystals may have widely different strengths, which depend on the relation of the direction of orientation to the applied stress.

Howe's modification of Rosenhain's amorphous theory seems to offer the most plausible explanation of the greater strength of the grain boundaries. Thompson's surface tension theory adds very little to our knowledge and rather complicates our conception as to what really happens. That surface tension actually exists, there is little doubt, but it does not appear to be a determining factor.

The author's own opinion as to what happens in the fracture of steel is: " The first effect of stress, therefore, is to cause a flow of amorphous material surrounding the grains, indicated micrographically by a ridging along the grain boundaries and a molecular yield in the space-lattice of the crystals. When the elastic limit is reached the amorphous cement, as determined by the strength and amount of it, breaks transversely, owing to its weakness in that direction, and the load is suddenly thrown upon the crystal. The plastic yielding, due to slipping, causes a sudden drop in the applied stress, which, after sufficient intercrystalline amorphization takes place, again causes the applied stress to rise,

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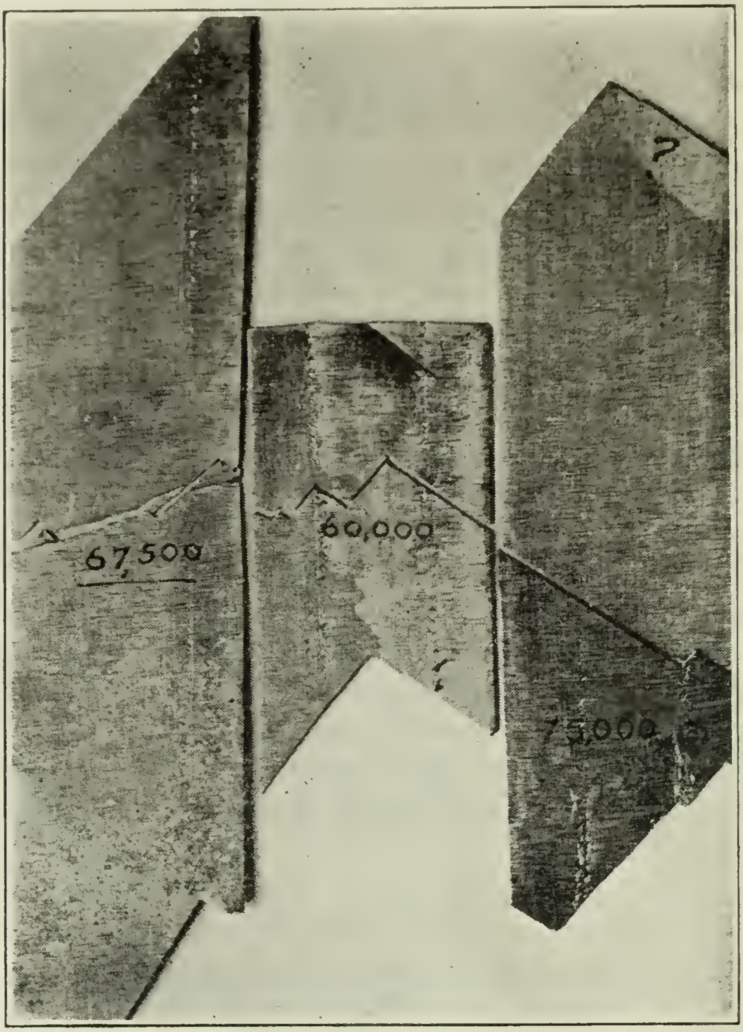
* Communicated by the Director.

but this time with considerable elongation. This is what the stress and strain diagram shows us actually happens. The unbroken part of the intercrystalline cement is not weakened and so still supports the crystal laterally."

The longer path of the intergranular cement, as compared



with internal shear, accounts for the fact that we do not have intergranular fracture in the case of suddenly applied loads. The strength of the grain boundaries, therefore, can be accounted for on the mere assumption that the amorphous boundary material is somewhat stronger than the crystalline phase without complicating our conceptions with further unnecessary assumptions.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

STUDIES IN NUTRITION: I. THE NUTRITIVE VALUE OF COCONUT GLOBULIN AND COCONUT PRESS CAKE.[1]

By Carl O. Johns, A. J. Finks, and Mabel S. Paul.

[ABSTRACT.]

NUTRITION experiments with albino rats show that normal growth can be attained by animals fed a ration in which either coconut globulin or coconut press cake forms the sole source of protein in an otherwise complete diet. Enough water-soluble vitamine for normal growth is contained in coconut press cake, and the presence of an appreciable, though insufficient, quantity of fat-soluble vitamine is indicated. Preliminary experiments show that coconut press cake is deficient in inorganic constituents, probably calcium, phosphorus, and chlorine.

LYSINE AS A HYDROLYTIC PRODUCT OF HORDEIN.[2]

By Carl O. Johns and A. J. Finks.

[ABSTRACT.]

HERETOFORE lysine has never been reported to be present in hordein, the alcohol-soluble protein of barley. Using the Van Slyke method, the Protein Investigations Laboratory found that lysine constitutes 1.01 per cent. of hordein.

PREVENTION OF DUST EXPLOSIONS AND FIRES IN GRAIN THRASHING MACHINES.[3]

By David J. Price.

[ABSTRACT.]

NUMEROUS explosions and fires in thrashing machines have been reported throughout the large grain-growing sections of this

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* Communicated by the Chief of the Bureau.

[1] Published in *Jour. Biol. Chem.*, v. 37, No. 4, April, 1919, p. 497.

[2] Published in *J. Biol. Chem.*, May, 1919.

[3] U. S. Department of Agriculture Bulletin 379.

country during the past few years. Since 1914 more than 700 have occurred in the Pacific Northwest alone, about 300 taking place in 1914 and almost as many in 1915. To determine the cause of these fires and explosions, and to develop methods of prevention, the U. S. Department of Agriculture has conducted an extensive investigation, during the course of which the following facts have been brought out:

Of the total number of machines thus affected in 1915 over 27 per cent. represented a complete loss, and 34 per cent. partial damage. the rest being but slightly affected.

More than 80 per cent. of the explosions and fires may be classified as wheat smut dust explosions, and approximately 76 per cent. originate near the cylinder in the front part of the machine. Over 75 per cent. of these occurrences were due to the ignition of the smut dust by the discharge of static electricity generated by the operation of the machine.

During the past three seasons three principal methods of prevention, developed and tested by the Department of Agriculture, have been generally adopted, and are now being made a permanent part of the machine equipment.

1. Installation of an effective fire extinguisher especially designed for thrashing machines. In the event of a fire, this not only saves the machine, but also prevents the spreading of flames to the nearby grain and straw.

2. The installation of an exhaust fan to collect and remove smut and dust from the separator, thus preventing the formation of an explosive mixture of dusts.

3. Installation of an effective grounding system for the removal of static electricity from the machine.

The field men of the Department have found that machines properly equipped in this way have not experienced explosions and fires, while those not so equipped have suffered extensive damage, with destruction also to the surrounding grain.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, April 16, 1919.)

Hall of The Franklin Institute,
Philadelphia, April 16, 1919.

President Dr. Walton Clark *in the Chair.*

Additions to membership since last report, 8.

The following gentlemen were nominated by the Board of Managers for Honorary Membership:

Dr. John A. Brashear, Pittsburgh, Pennsylvania.

Prof. Heike Kamerlingh Onnes, Leiden University.

Dr. Thomas Alva Edison, Orange, New Jersey.

Prof. Theodore William Richards, Harvard University.

Col. John J. Carty, Chief Engineer, American Telephone and Telegraph Company.

Prof. Hendrik Antoon Lorentz, Leiden University.

Admiral David Watson Taylor, Chief Constructor, Bureau of Construction and Repair, United States Navy.

Senator Guglielmo Marconi, Rome, Italy.

Sir James Dewar, The Royal Institution, London, England.

Major General George Owen Squier, Chief Signal Officer, United States Army.

The nominations were duly seconded, and the gentlemen were unanimously elected.

The President advised the meeting that the Institute had become the residuary legatee under the will of the late Henry W. Bartol, and that to benefit by the will it was necessary for the meeting to adopt a resolution accepting the bequest. On motion, duly seconded, it was: *Resolved*, That the bequest and trust contained in the last will and testament and codicil of Henry W. Bartol be, and the same are hereby, accepted. The resolution was passed unanimously.

A report of progress was presented by the Committee on Library.

The President referred to the great loss the Institute had sustained through the death of its late Vice-President, Mr. Louis E. Levy, and recognized Mr. Coleman Sellers, Jr., who said:

> " In February last, the Institute lost by death one of its most useful and most devoted members, Mr. Louis E. Levy, Vice-President.
>
> " The Board of Managers at its meeting on February 19th, adopted an appropriate minute, and it seems fitting and desirable that the Institute itself should make a formal record of its loss and express in some measure its sense of appreciation of the character and services of such an exceptional man."

And then moved the adoption of the following minute:

> "It is with a deep sense of its loss that The Franklin Institute of the State of Pennsylvania hereby records the sudden death on February 16, 1919, of its Vice-President, Louis E. Levy.
>
> "Mr. Levy joined the Institute in 1881, was elected a member of the Board of Managers in 1903 and a Vice-President in 1916. In 1896 he was appointed a member of the Committee on Science and the Arts, for which he was peculiarly qualified by his broad scientific knowledge and inventive ability.
>
> "The thirty-eight years of Mr. Levy's membership were years of willing, devoted and effective service to the Institute. There was probably no one of the Institute's activities in which he did not at some time participate. He was always prepared to do more than his share of any work required, and his genial character and kindliness endeared him to his associates.
>
> "He was an unusual combination of desirable characteristics. For the breadth and depth of his knowledge and his ingenuity, he was remarkable. In his personality he was lovable. In character in all respects he was estimable. He was in truth a many-sided man, and all of his ability and attainments were freely given to his fellow man. He will long be mourned and missed by a wide circle of people of all sorts and conditions whom he served in some helpful manner. To The Franklin Institute he can hardly be replaced."

This motion was seconded by Prof. A. E. Outerbridge, Jr., who gave a brief account of Mr. Levy's scientific and technical achievements. The motion was unanimously carried.

The Chairman then introduced Hollis Godfrey, Sc.D., Eng.D., LL.D., D.C.L, F.R.G.S., President of Drexel Institute, Philadelphia, who presented the paper of the evening, entitled "Shipbuilding Analysis." The speaker outlined a very complete study he had made of the subject.

Lantern slides of diagrams and from original photographs taken at various shipyards were exhibited for the purpose of illustration. The progress of the work through various stages was also shown by means of charts, blue prints, card records, and other details. The speaker stated that the work as described made possible a material shortening of the time now taken for ship construction, and would also prove of importance in the education of shipyard workers.

After a brief discussion, the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

RESOLUTION ADOPTED BY THE BOARD OF MANAGERS ON THE OCCASION OF THE DEATH OF LOUIS EDWARD LEVY.

PHILADELPHIA, February 19, 1919.

The Board of Managers of The Franklin Institute learns with sorrow of the death of its esteemed fellow-member, Mr. Louis E. Levy, whose many activities in the work of the Institute have been of great value to it and to the public the Institute is organized to serve, and adopts the following Resolution to be published in the JOURNAL and a copy to be transmitted to his family:

> RESOLVED, That through the death of Louis Edward Levy, The Franklin Institute has lost one of its most faithful and loyal friends.
>
> Becoming a member of the Institute in October, 1881, he was, from the beginning of his membership, intensely interested in its different activities.
>
> Appointed a member of its Committee on Science and the Arts in 1896, he served uninterruptedly either as member or chairman of that Committee. His genial personality, coupled with a clarity of insight, won for him a permanent place as a member of that Committee, and established between him and his associates a cordiality of relations that bound them to him as lifelong friends.
>
> In 1916 he was elected to the Vice-Presidency of the Institute, a position which he filled with distinction.
>
> During this term of thirty-eight years as member and official in this Institute, his services were given without stint to advancing its interests.
>
> A man of high inventive skill, his discoveries in the field of the graphic arts have received distinguished recognition from the World's Fairs at Chicago, Paris, St. Louis and San Francisco, as well as the highest award in the gift of The Franklin Institute, the Elliott Cresson Gold Medal.
>
> His work as editor, author and publisher is well known and appreciated in Philadelphia, while his articles in technical journals have been read with interest and profit. As Chairman of the Committee on Publications, his literary ability and experience enabled him to render efficient and valued service to the JOURNAL in both the literary content and technical excellence of which he was deeply interested.
>
> He was a member of many technical societies, interested not only in those dealing with his own immediate interests, but also in those which treated of general scientific subjects, industrial improvements and social betterment.
>
> A man of wide experience, he formulated a broad philosophy which was optimistic in its faith in the ultimate well-being of mankind.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, April 2, 1919.)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 2, 1919.

MR. BENJAMIN FRANKLIN *in the Chair.*

The following reports for reconsideration and final action were presented:

No. 2708: Waterbury Hydraulic Speed Gear. Potts Medal jointly to Reynold Janney, of New York, N. Y., and Harvey D. Williams, of Wallingford, Conn., adopted.

No. 2714: Snook's X-Ray System. Referred back to Committee for revision.

For first reading:

No. 2728: Landreth Electrolytic Sewage Process.

R. B. OWENS,
Secretary.

SECTIONS.

Mechanical and Engineering Section.—A meeting of the section was held in the Hall of the Institute on Thursday evening, March 6, 1919, at 8 o'clock, with Mr. G. H. Clamer in the chair. The minutes of the previous meeting were approved. The presiding officer introduced Robert Grimshaw, C.E., of New York City, a member of the Faculty of New York University, who delivered a lecture on "The Problem of Cost Reduction." The importance of the problem was shown; the factors (men, materials, markets, machines, and methods) and the subjects (labor, materials, and oncost) were described. Methods were enumerated for the solution of the problem by reducing cost of labor and material and oncost, and the results obtained were discussed. The paper was discussed. A vote of thanks was tendered Professor Grimshaw, and the meeting adjourned.

JOSEPH S. HEPBURN,
Acting Secretary.

Section of Physics and Chemistry.—A joint meeting of the section, and the Physics Club was held in the Hall of the Institute on Thursday evening, April 3, 1919, at 8 o'clock, with Dr. Harry F. Keller in the chair. The minutes of the previous meeting were approved as read.

W. J. Humphreys, Ph.D., Professor of Meteorological Physics in the U. S. Weather Bureau, delivered a lecture on the "Optics of the Air." Perspective, refraction, diffraction, and diffusion in the atmosphere were discussed with special reference to such phenomena as the rainbow, the halo, the azured sky, and the twilight glow. The lecture was illustrated with lantern slides. Several members and visitors participated in the discussion. On motion of Doctor Alleman, seconded by Doctor Hoadley, a vote of thanks was extended to Doctor Humphreys. The meeting then adjourned.

JOSEPH S. HEPBURN,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, April 9, 1919.)

RESIDENT.

MR. CHARLES E. BRINLEY, President, The American Pulley Company, 4200 Wissahickon Avenue, Philadelphia, Pennsylvania.

MR. EDWIN FRANK, Mechanical Engineer, C. H. Wheeler Manufacturing Company, and for mail, 1426 Diamond Street, Philadelphia, Pennsylvania.

MR. J. HARVEY GRAVELL, Engineer, Tilghman-Brookbank Sand Blast Company, 1126 South 11th Street, Philadelphia, Pennsylvania.

PROF. WILLIAM OTIS SAWTELLE, Department of Physics, Haverford College, Haverford, Pennsylvania.

NON-RESIDENT.

MR. T. LEES BARTLESON, Chemist, Experimental Station, E. I. du Pont de Nemours Company, and for mail, 2530 West 18th Street, Wilmington, Delaware.

MR. S. C. HOLLISTER, Civil Engineer, Concrete Ship Section, Emergency Fleet Corporation, and for mail, 4420 Chestnut Street, Philadelphia, Pennsylvania.

NON-RESIDENT LIFE.

MR. HENRY FRED COLVIN, 2D, Student, 56 North Maple Avenue, East Orange, New Jersey.

ASSOCIATE.

MR. GEORGE HOLMES, Technical Journalist, 164 West 146th Street, New York City, New York.

CHANGES OF ADDRESS.

MR. ROBERT J. ANDERSON, U. S. Bureau of Mines, Experiment Station, Pittsburgh, Pennsylvania.

MR. ENRIQUE BUSTOS, Chilian Consul, Parkway Building, Philadelphia, Pennsylvania.

DR. A. S. CUSHMAN, Director, The Institute of Industrial Research, 1845 B Street, N. W., Washington, District of Columbia.

MR. THOMAS DUNCAN, Lafayette, Indiana.

MR. HENRY S. HALE, 2005 Chestnut Street, Philadelphia, Pennsylvania.

MR. G. L. KOTHNY, 2208 Rittenhouse Street, Philadelphia, Pennsylvania.

MR. W. J. MCGURTY, 3607 Forest Park Avenue, Baltimore, Maryland.

MR. W. N. RUMELY, 230 East Pearson Street, Chicago, Illinois.

MR. F. H. SHELTON, 228 South 21st Street, Philadelphia, Pennsylvania.

MR. C. S. WOOD, 315 South 15th Street, Philadelphia, Pennsylvania.

MAJOR ARTHUR W. YALE, Medical Corps, Post Surgeon, Air Service, Flying School, Rockwell Field, San Diego, California.

NECROLOGY.

Louis Edward Levy, photochemist, inventor, author and editor, died suddenly on February 16, 1919.

Mr. Levy was born in the historic town of Pilsen, Bohemia, on October 12, 1846, and came to the United States with his parents in May, 1854.

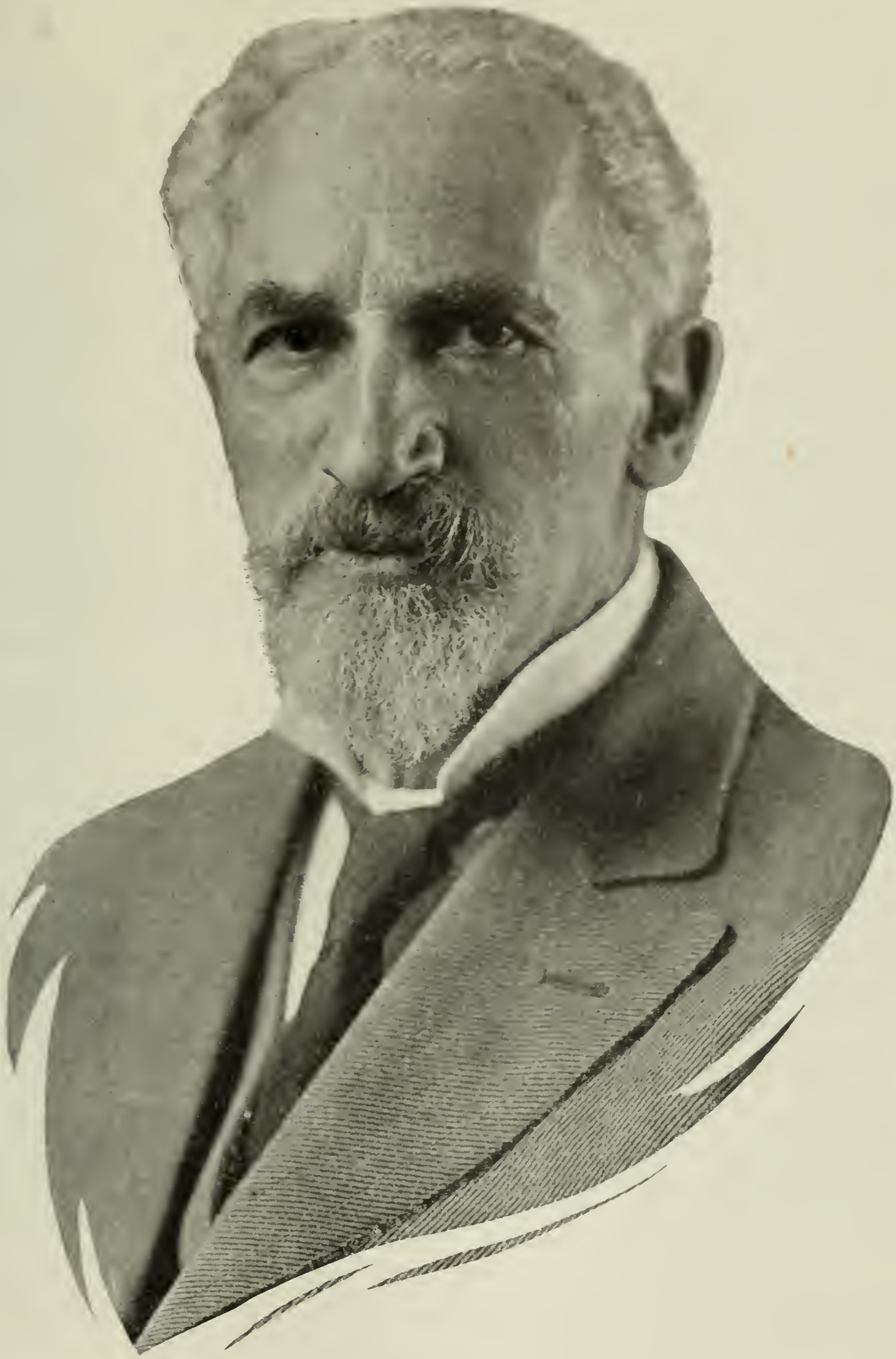
His education began in the public schools of Detroit. While attending school he obtained a position with the City Surveyor of Detroit, which gave him an insight into civil engineering and an opportunity for further study. The years 1866–67 he devoted to special courses in mathematics and physics in the University of Michigan.

He was greatly interested in meteorology and acted as observer for the United States Government at the Lake Survey Station, Detroit, from 1866 to 1873. During 1869 and 1870 he devoted much time to the study of microscopic photography. Four years later he began a series of investigations with a view to producing engravings by photochemical means. This resulted in what was known commercially as the Levytype, a process for the rapid production of half-tone illustrations for newspapers and magazines. The first American patent in this field of the graphic arts was granted to Mr. Levy in 1875. In this year the Levytype Company was established in Baltimore. After two successful years it was thought that Philadelphia would offer a still larger field for work of this character and the plant was removed to this city, where it was continued for twenty-two years.

In the meantime Mr. Levy continued his researches and experiments and introduced from time to time new apparatus and processes which greatly simplified the production of half-tone printing plates. In 1887, with his brother, Mr. Max Levy, he invented the "Half-Tone Screen"; in 1892, the "Photo-Mezzotint" process; in 1896, the "Levy Acid Blast," a new method of etching; and still more recently the "Etch-Powdering Machine."

His work as editor and publisher extended over a period of many years. *The Sunday Mercury*, an illustrated weekly, was under his management for five years, and he also directed the publication of the *Evening Herald*, of Philadelphia, for a like period. He organized the Iconographic Publishing Company, which published seven volumes of the Iconographic Encyclopedia, an elaborate series based on a well-known foreign work. In 1896 he edited and published the volume, "Cuba and the Cubans," from the Spanish, by Raimundo Cabrera, and for two years collaborated with this author in the publication of the magazine *Cuba y America*. He was author and publisher of "The Jewish Year," 1894; compiler, editor and publisher of "Wolf's American Jew as Patriot, Soldier and Citizen," 1895; author and publisher (1896) of "Business, Money and Credit." In collaboration with Mr. Hugo Bilgram he issued "The Cause of Business Depressions" in 1914.

His honors were many; he received medals, diplomas and premiums from the World's Columbian Exposition, Chicago, 1893; decoration and diploma from the Imperial Russian Photographic Society, Moscow, 1896; gold medals from the Expositions at Paris, 1900; Buffalo, 1901; St. Louis, 1904, and San Francisco, 1915. His various inventions were also recognized by The Franklin Institute, which awarded him the Elliott Cresson Medal for his Acid-Blast Method and Apparatus for Etching Metal Plates, in 1900, and the same



LOUIS E. LEVY
1846–1919

medal for his Machine for Powdering Plates for Etching, in 1904. The city of Philadelphia awarded him the John Scott Legacy Medal and Premium in 1897 for his Screens for Photo-Mechanical Engraving, upon the recommendation of the Institute.

Space prevents a detailed enumeration of the benevolent and charitable organizations and associations with which Mr. Levy was actively connected.

He became a member of The Franklin Institute on October 29, 1881, and in 1894 was appointed a member of the Committee on Library, serving continuously until the time of his death. He was three times elected Chairman. His varied knowledge of books and literature made him an invaluable member of this committee. In 1896 he was elected a member of the Committee on Science and the Arts and acted as its Chairman in 1901. Here again his knowledge of technical matters and industrial inventions and progress made him extremely useful. He was regular in his attendance, and served on many subcommittees of investigation. In 1903 he was elected a member of the Board of Managers and at the same time was appointed a member of the Committee on Publications, for the past ten years acting as its Chairman. To this Committee he undoubtedly gave his best efforts, and because of his wide experience in the engraving, printing, and publishing trades he was especially qualified to render valuable service in this important branch of the Institute's work. Since 1916 he has been one of the vice-presidents of the Institute.

At the funeral services held on February 19, Dr. Walton Clark, President of the Institute, made the following remarks:

"To be permitted to speak of Mr. Levy to a group of his friends, gathered to pay to him the last sad tribute of affection and respect, is an honor that I value highly.

"Because my acquaintance with Mr. Levy and my association with him was all in connection with the work of The Franklin Institute, it is of his devotion to that work, and of his influence upon it, and upon the men privileged to work with him, that I shall briefly speak to you.

"The words at my command are inadequate to express to you the affection and respect in which I and my associates in The Franklin Institute hold the memory of our departed friend.

"Mr. Levy served the Institute, and, through it, the public, for more than a generation. At intervals during that period of time he acted as Chairman of each of the more important committees. For the ten years just ended he was Chairman of the Publications Committee, and for this work his extended knowledge of the technique of the publisher's art, and his wonderful command of the English language preëminently prepared him. His was a large share in insuring the JOURNAL of the Institute an honored place on the shelves of the scientific libraries of the world.

"Mr. Levy's racial characteristics—his imagination rich and fertile, his passionate devotion to scientific truth, the accuracy of his mental operations, his instinct for thrift—each contributed to make his service of the highest value to the Institute and to the public it is organized to serve.

"A wonderful story of service is written against Louis Levy's name on the records of the Institute he loved so well—a record not measured by years—though, if so measured, unparalleled by any in the experience of our generation.

"Through all the serious and important labors of Mr. Levy of which I have knowledge, he bore a cheerful, confident spirit—at times he was even playful, and often our somewhat sombre walls echoed his laughter and the laughter his humor provoked.

"It is good for us, his associates, Jew and Gentile, who have shared in the work of our honored Institution for the past twenty years, that Louis Levy has been of our number."

"The announcement of the sudden death of our esteemed friend Mr. Louis E. Levy is a great shock to me, and it will be a serious loss to The Franklin Institute as well as the community, for he was a man of broad philanthropy, who devoted himself to works for the betterment of the community and was unsparing of his time and energies in the pursuit of science, literature and the arts, that they might be applied in the best manner to the general welfare.

"He was faithful in the discharge of duty, courteous in his discussions, facile in his resources and just in his judgments, so that his opinions carried conviction and his results were accepted as sound. In the evolution of the graphic arts he was a pioneer as to economy, facility and efficiency, and in this field has added greatly to the prompt dissemination of useful knowledge by the language of form rather than words, even though 'fitly spoken.'

"His transition from the physical to the spiritual was but an illustration of the beautiful description of St. Paul where he says:

> "'We shall not all sleep but we shall be changed. In a moment, in the twinkling of an eye, at the last trump: for the trumpet shall sound, and the dead shall be raised incorruptible, and we shall be changed.' When 'Death is swallowed up in victory.'
>
> "'For as much as ye know that your labor is not in vain in the Lord.'

"Or as St. James says:

> "'For what is your life? It is even a vapour, that appeareth for a little time, and then vanisheth away.'

"But the influence of such a life as that of our friend is imperishable and has left its imprint upon the lives of many who have never had the pleasure of his acquaintance, 'and his works do follow him.' His was a painless transition and a joyful inheritance, for he was a 'Good and faithful servant,' whose memory we shall ever cherish."

LEWIS M. HAUPT.

"A life so full of work and philanthropy as that of Louis Edward Levy would seem to suggest a hunger for odd days of sport and recreation. But when Mr. Levy was not working on half-tones, or writing for technical papers, or winning medals, or on any special errand, he was at The Franklin Institute. He enjoyed its books, he liked to go over its reports, he was proud to see the long roll of savants in its lecture course.

"In the analysis of a life strong in mental achievement we must give a generous place to the general as well as the particular. We look, for instance, on William L. Marcy as an efficient Cabinet officer and as one of the hardest political fighters of his generation. It was because he was generally breast deep in the hottest line of party warfare that he loved the quiet hours of retirement over Plato, something apart from motions and debates was the tonic that steadied him. At intervals the man with a hundred business irons in the fire goes out for a botanical ramble with a friend or passes a night in an observatory. He does not want to be an Asa Gray or a Simon Newcomb, but he yearns for the scientific atmosphere that braces him for the coming rush of orders beyond his power to supply or for the time of panic when banks go down twenty or so in a day.

"Sometimes the man who is renowned for his mastery of a specialty preserves life and reason because he is not at all times and everywhere a specialist, because he takes a general interest in something outside his chosen themes. Even the law, that proverbially jealous mistress, permits flirtations, for no year passes without its proof that a Warwick can write on French history, or a Brewster deliver lectures on colonial missions, or a John G. Johnson gather paintings from all points under heaven.

"Louis E. Levy's life was longer, broader and happier because he knew what science was doing in bridge building, in chemistry, in stellar research, in sanitation, in steel manufacture, in gas and electricity. After all, the specialist cannot forget that the wisest of Israel's kings was interested in plants, from the cedar of Lebanon to the hyssop that groweth out of the wall."

ROLAND RINGWALT.

Charles A. Brinley was born in Hartford, Conn., August 23, 1847, the son of George Brinley and Frances Ellen Terry. After attending the Hartford High School and before entering college he spent a year, chiefly in Arizona and California, as a member of the staff of the Geological Survey of California, with Clarence King and James T. Gardner, under the direction of Prof. Josiah D. Whitney.

Mr. Brinley graduated from the Sheffield Scientific School, Yale University, in 1869, and passed three more years in post-graduate work in chemistry and metallurgy in the same school.

In 1872 he came to Philadelphia, entering the employ of the Midvale Steel Company as a chemist, and two years later was made superintendent. He brought to Midvale a knowledge of metallurgical chemistry possessed by few men at that time, and by his knowledge, combined with a natural aptitude for hard work and management, he reorganized the production methods of a struggling concern and made uniformly good steel, so that when he left Midvale ten years later the company had attained a leading position in the manufacture of high-grade special steel. As superintendent of Midvale he was the first in this country to make open-hearth steel axles to meet the specifications of the Pennsylvania Railroad, the first to make open-hearth steel locomotive tires, the first to make gun forgings to meet the requirements of the United States Government and the first to roll angles, channels and I beams from rectangular steel billets. The initial four thousand tons of these shapes which came from the rolls were used in the suspended structure of the Brooklyn Bridge, and, as he says in a private memorandum written in 1909—"By the Grace of Providence they are still there." It was during the time that Mr. Brinley was superintendent at Midvale and under his supervision that the late Frederick Taylor began his work of investigation in scientific production methods.

After ten years at Midvale, Mr. Brinley was invited to become general manager of the Franklin Sugar Refinery in Philadelphia. He accepted the invitation and remained in that capacity until 1892, when the then owners sold

CHARLES A. BRINLEY
1847–1919

their interest. Although the new owners desired to retain his services, he resigned and retired temporarily from active business.

The next few years were spent in activities in relation to civic betterment and education. Two books were published, "The Voters' Handbook" and "Citizenship." He became president of the University Extension Society and was influential in establishing it upon a substantial and permanent basis.

In 1898 Mr. Brinley organized the American Pulley Company, the leading concern in the United States for the manufacture of pressed steel pulleys. He became managing director of the company soon after its organization and later its president. He continued as executive of the company until the time of his death.

As an organizer and executive he was untiring in examination and perfection of methods for efficiency in manufacture and for accurately recording the results of work done, and his mind was ever active in planning for the welfare and comfort of his employees.

Although the major part of his life was spent in the active charge of manufacturing concerns, his mind possessed the qualities of the true scientist and philosopher, and he found opportunity to interest himself in many subjects outside of purely commercial affairs. He read widely and was a sound critic of literature and art, although his abilities in these respects were known to few except his personal friends.

Mr. Brinley became a member of The Franklin Institute in 1899, and in 1903 was elected to its Board of Trustees, in which capacity he served until his death on March 2d of this year. He was a member of the Shakespeare Society of Philadelphia, a member of the Board of Directors of the Pennsylvania Institution for the Deaf and Dumb, and one of the Managers of the Western Saving Fund Society of Philadelphia.

Mr. Robert M. Dixon, 21 North Walnut Street, East Orange, New Jersey.

Mr. Jesse T. Vogdes, 127 City Hall, Philadelphia, Pennsylvania.

Mr. R. Norris Williams, 8124 St. Martin's Lane, Chestnut Hill, Philadelphia, Pennsylvania.

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BOOK NOTICES.

CHEMISTRY IN OLD PHILADELPHIA. By Edgar F. Smith, University of Pennsylvania. 106 pages, 8vo. Philadelphia, J. B. Lippincott Company, 1919. Gift from the Author.

Doctor Smith tells us that the first resident of Philadelphia to make a contribution in chemistry to be published in a scientific periodical was Doctor de Normandie, who, though a practicing physician, found time to undertake real research in chemistry. His paper, which bears date of 1768, was published in the first volume of the *Transactions of the American Philosophical Society*. It discusses the composition of a sample of water from Bristol, Pa. The paper is of great importance and interest, because, Doctor Smith points out, de Normandie used the balance in his work. It has always been recognized that the balance is the characteristic instrument of the chemist, and the world has given to Lavoisier the credit of first making it the laboratory aid *par excellence*. French chemists would have us believe that chemistry was born when Lavoisier began to test his results by weight. Wurtz begins his essay on "Chemical Theory" with the words "La chimie est une science française. Elle fut fondée par Lavoisier de mémoire immortelle." This is going a little too strong, though there is no question of the value of Lavoisier's work. Doctor Smith points out, moreover, that John Rey (15— to 1645) also used the balance.

Philadelphia chemists will be greatly interested in the details that Doctor Smith gives about the early ventures into chemistry by residents of the "green countrie toun" when it was the metropolis of America, and will be grateful to him for poring over musty tomes and dusty volumes to summarize the data. One eminent chemist whom America boasts, Doctor Priestley, does not function in Philadelphia history. He was offered, indeed, a professorship of the science in this city, but he refused it, and is reported to have said that he "never saw a town he liked less." Yet this may have been a remark in a temporary petulant mood, for Doctor Smith shows that he visited Philadelphia not infrequently, and found enjoyment in some of its personal associations.

HENRY LEFFMANN.

CATALYTIC HYDROGENATION AND REDUCTION. By Edward B. Maxted, Ph.D., B.Sc., F.C.S. 101 pages, contents and index, illustrations, 16mo. Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.25 net.

There is crowded into the hundred and one pages of this book an immense amount of information on the subject of the hydrogenation of both natural and artificial substances by means of inorganic catalysts. Most of the reactions are illustrated by symbols. A brief historic introduction is given, by which we learn that the impetus to this line of research was mainly given by Sabatier and Senderens in 1899, whose papers appeared in *Comptes Rendus* from 1900 onward, and who first studied especially the activating properties of nickel. Other earlier workers are: de Wilde, Saytzeff and Kolbe, of Germany, and Cooke, of England. Many remarkable reactions, which will in time have most important practical bearings, are given. Thus Sabatier and Senderens found that by passing a mixture of carbon monoxid and hydrogen over nickel, methane is formed easily and smoothly at 250°C., and that even carbon dioxid can be substituted for the monoxid if the temperature is raised to 300°C.

The book is clearly printed on good paper and is a valuable addition to an important field of synthetic chemistry. The reviewer wishes to record his objection to the use of the phrase "*in statu nascendi*" in place of the good English "in the nascent state." There is some justification for the occasional use of a quotation in a foreign language, but scraps of Latin or French have no place as mere substitutes for English phrases just as clear and explicit. Such practices remind us of the days—now possibly, happily gone forever—when our young American students returning after a year or so of German laboratory would persist in speaking of an "Oese" and a "Schaelchen" instead of a "loop" and a "dish."

HENRY LEFFMANN.

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Catalytic Hydrogenation and Reduction, by Edward B. Maxted. 104 pages, illustrations, 12mo. Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.25.

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Production of Garnet in 1918. ANON. (*U. S. Geological Survey Press Bulletin,* No. 405, April, 1919).—There are many kinds of garnet, and the most widely known kinds are the least abundant. Garnets that can be cut into the well-known handsome and sometimes highly prized gems are rare. On the other hand, some garnets are in many places so abundant that they are frequently spoken of by mineralogists as "ordinary garnet." Some varieties of ordinary garnet, like many other common things of unattractive appearance, are far more useful than the rare and beautiful varieties, and probably the total value of the common garnet annually consumed greatly exceeds the value of all the gems. Certain varieties of common garnet are used as abrasive materials—that is, they are used for cutting and polishing by grinding or rubbing. Abrasive garnet is used chiefly in the form of so-called sandpaper and cloth. Strange to say, in the United States at the present time sandpaper is never made with sand; most commonly it is made with crushed quartz, and some of it is made with garnet, emery, corundum, and artificial abrasives. The common quartz paper is generally called sandpaper; the others go by the names garnet paper, emery paper, corundum paper, etc.

According to statistics compiled by Frank J. Katz, of the United States Geological Survey, Department of the Interior, the mine output of abrasive garnet in the United States in 1918 was 4127 short tons; and the quantity of milled garnet marketed was 4600 tons, valued at $242,401. Producers of garnet reported stocks in hand at the end of the year amounting to 2030 tons.

During 1918 the price of abrasive garnet produced by quarry and mill operators ranged from $25 to $60 a short ton and averaged $52.70. The mine ouptut was somewhat smaller in 1918 than in previous years, in spite of a heavy demand for garnet; this decrease was due largely to difficulty in holding an adequate supply of skilled labor at the quarries and mills. The garnet produced came chiefly from Warren County, N. Y.; small amounts were contributed also by Merrimack County, N. H., and Clay County, N. C.

CURRENT TOPICS.

Rare Elements as Paint Pigments. H. A. GARDNER. (*Educational Bureau, Paint Manufacturers' Association of the United States,* Circular No. 62, April, 1919.)—Many of the rarer elements that heretofore have had but little industrial application received much consideration during the war-time period. It is probably safe to state that many of them will be used as the basis of preparations destined to become of great importance in the arts. Their possibilities as pigment bases, for instance, for several years have engaged the writer's interest. Among the more obscure or not commonly known metals that he has experimented with are molybdenum, cerium lanthanum, selenium, thorium, titanium, tungsten, uranium, vanadium, zirconium, beryllium and radium. Nearly all of the above metals, in the form of their respective insoluble compounds, have a high refractive index and consequently produce, when ground with oil, very opaque mixtures having a hiding power comparable with lead and zinc pigments.

From the standpoint of war-time usage, radium pigments have been of the greatest interest, substantial quantities having been used for aircraft instruments and other paraphernalia of modern warfare. The radium may be applied as a salt to an active or sympathetic base having real pigment properties, such as zinc sulphide. This activated pigment is mixed with a thin, clear varnish that acts as binder. Only small amounts of radium salts are required in such paints to produce energetic vibrations that send out active radiations in the form of a soft greenish glow. These paints have almost entirely replaced the old luminous calcium sulphide paints which, although comparatively low in price, depend upon absorption of energy from sunlight. The only substitute for radium is mesothorium, an element found in monazite sand that is mined in certain of our southern states. Its longevity is not as great as that of radium.

Selenium, an element analogous in some of its properties to sulphur, which is obtained during the smelting and refining of copper, has had but little industrial application. The writer has prepared several most interesting pigments from it (the selenites of lead and borium, for instance) which are very white and of fine grain. Their exceptionally high refractive index gives them intense opacity. Other pigments of a closely related nature may be produced from beryllium, an element found as a silicate or aluminate in several eastern states. The oxide and similar products of zirconium have a very high degree of whiteness, opacity and permanence. From titanium, an element which is widely distributed, many most interesting compounds have been produced, and it is highly probable that some day they will be used to a great extent as pigments where great opacity, permanence and other closely related physical properties are desired. Among the more common elements from which white pigments may be made are arsenic, antimony, bismuth and tin. The toxic nature of some of these compounds and their high price as compared with lead and zinc pigments have limited or prevented their use.

Metal Powders as Pigments. H. A. Gardner. (*Educational Bureau, Scientific Section, Paint Manufacturers' Association of the United States,* Circular No. 61, April, 1919.)—Finely divided metal powders have specific uses as pigments. Zinc powder (zinc dust), for instance, has been employed to some extent as a pigment, and for many years has formed a substantial part of the antifouling and anticorrosive ships' bottoms paints used by the Navy Department; for instnace, a paint made of finely divided zinc powder suspended in a heavy bodied drying oil, a spar varnish, or a lacquer could be used as a "liquid galvanizing." Great fineness of the zinc powder is the chief requisite and the paint should contain at least 90 per cent. of metallic zinc of such fineness that 96 per cent. shall pass through a 300-mesh screen. When applied to a bare iron surface, there would be a water-proof film containing a metal that would protect the iron from corrosion. Aluminum, lead, copper, iron and other metals in powdered form have found special applications as surface coatings.

When metal powders are employed as primer paints, those metals should preferably be used that have a higher solution tension than that to which it is applied. If two metals are placed in contact in the presence of water a primary battery is formed, and galvanic action ensues. The electropositive metal will go into solution and the electronegative metal will be unacted upon. In the order of their solution tendencies, the metals commonly used are: aluminum, zinc, iron, nickel, lead, copper, tin and antimony. Any of these metals when placed in contact in the presence of water with another metal lower in the series will tend to protect the latter metal from corrosion. Zinc is the only commercially available metal of moderate price, and applicable as a coating, that is higher in the series than iron. This metal is therefore theoretically ideal to use as a protective coating on iron surface when applied in the form of galvanizing. The film of zinc, even when abraded, will have a marked protective influence upon the adjacent areas of bare metal.

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TREE TELEPHONY AND TELEGRAPHY.*

BY

MAJOR GENERAL GEORGE O. SQUIER,

Chief Signal Officer, United States Army.
Member of the Institute.

I. FOREWORD.

In 1904 the author conducted some experiments with a view to utilizing growing trees as antennæ for radio telegraphy and discovered the efficacy, in a general way, of using a direct metallic contact to certain trees (principally eucalyptus) to increase the audibility of radio signals.

My attention was first called to this phenomenon during the course of summer manœuvres of the Army at Camp Atascadero, California, where, due to the prevalence of the dry season and the unusual character of the soil, it was found that the regular Army buzzer telephone and telegraph sets were inoperative with any ordinary ground or earth but became operative when connected to a metallic nail driven in the trunk or roots of a tree. This incident led the author to pursue the subject experimentally in the autumn of 1904, continuing the experiments to the range of frequencies then employed in radio telegraphy.

From the account of these experiments I quote the following selected paragraphs:[1]

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* Communicated by the author.

[1] Reference. "On the Absorption of Electromagnetic Waves by Living Vegetable Organisms." By George O. Squier, Ph.D., Major, Signal Corps, U. S. A. Official Report to the War Department on the Military Manœuvres in the Pacific Division, 1904.

[Note.—The Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.]

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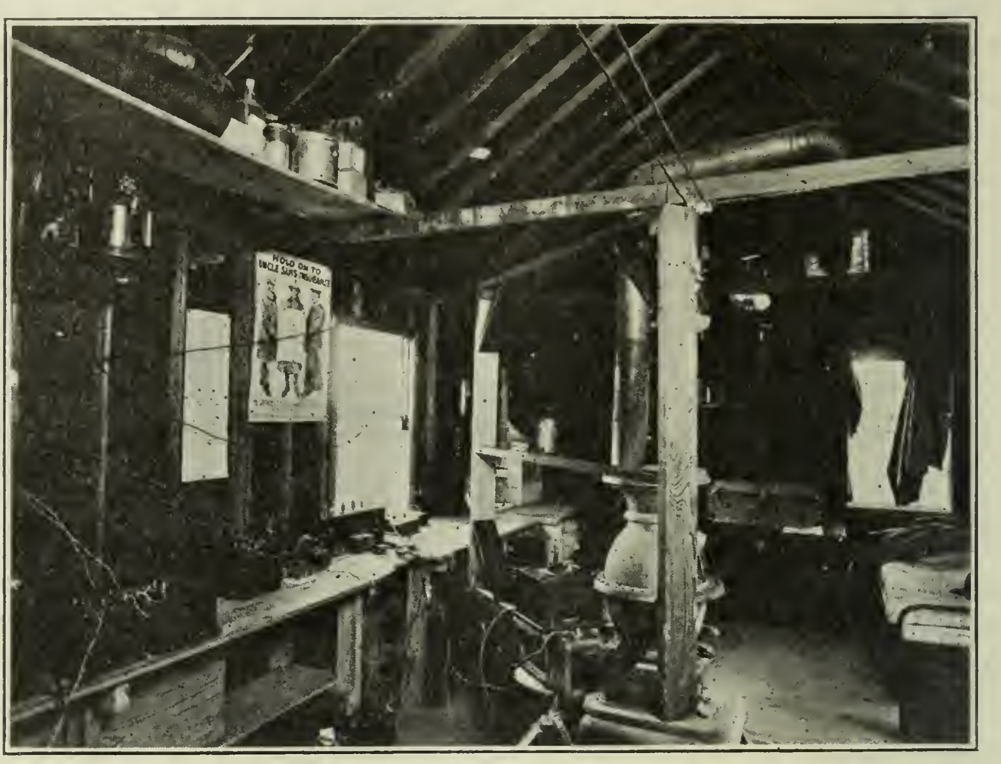
"It would seem that living vegetation may play a more important part in electrical phenomena than has been generally supposed. We have seen that living vegetable organisms absorb and conduct electromagnetic oscillations over a wide range of the electromagnetic spectrum, beginning with sunlight, whose electrical action in the plant cell is at present little understood, and extending to waves of identical character, but of immensely greater lengths, such as Hertzian radiation, telephonic waves, and oscillations of the ordinary low frequencies used in commercial electric transmission lines. Disruptive discharges between vegetable electrodes, and electrostatic effects between vegetable surfaces are easily produced.



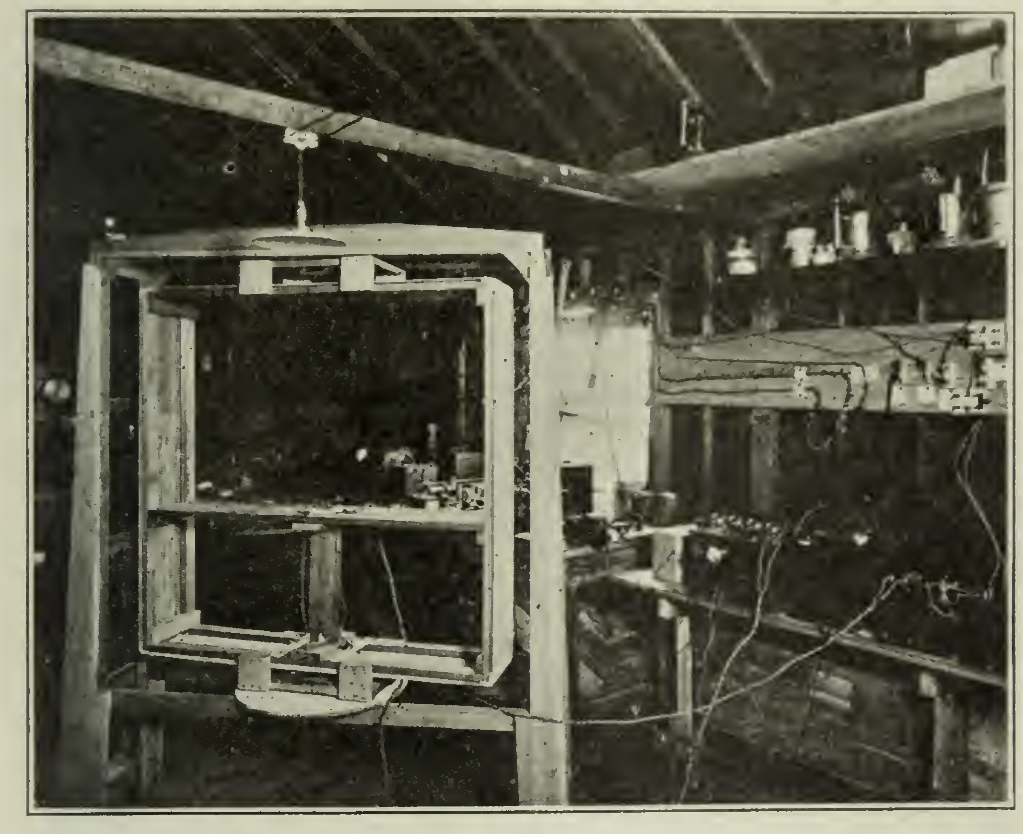
Floraphone short-wave receiving apparatus.

"In view of what has been accomplished in space telegraphy within the last seven or eight years, it is difficult to predict to what extent this means of communication may be ultimately developed. If, as indicated above in these experiments, the earth's surface is already generously provided with efficient antennæ, which we have but to utilize for such communication, even over short distances, it is a fascinating thought to dwell upon in connection with the future development of the transmission of intelligence.

"Since a transmitting station is a central point for electromagnetic waves sent out in all directions over the surface of the earth, a large class of information, such as meteorological reports, crop reports, and general news items of interest to all, may in time be sent from central points, to be received at many places within the radius of influence of the signal station, and this, too, by the simplest forms of apparatus.

"It is seen that a growing tree, covered with foliage, is influenced inductively by electrical disturbances outside of itself, and in fact becomes generally responsive to induced electrical oscillations. It should offer, therefore, a promising means of studying meteorological effects of an electrical character, particularly those of lightning discharges, and electricity of the air. One of the first practical rules for the preservation of life against lightning is to avoid the vicinity of a tree.

"Our great forest areas may exercise an influence in maintaining a general equilibrium between the electrical charges of the upper atmosphere and the earth, which has not been fully realized. On this point, comparisons between observatories from the interior of great desert areas devoid of any vegetation, with those from other portions of the earth's surface well covered with forests, would be instructive.



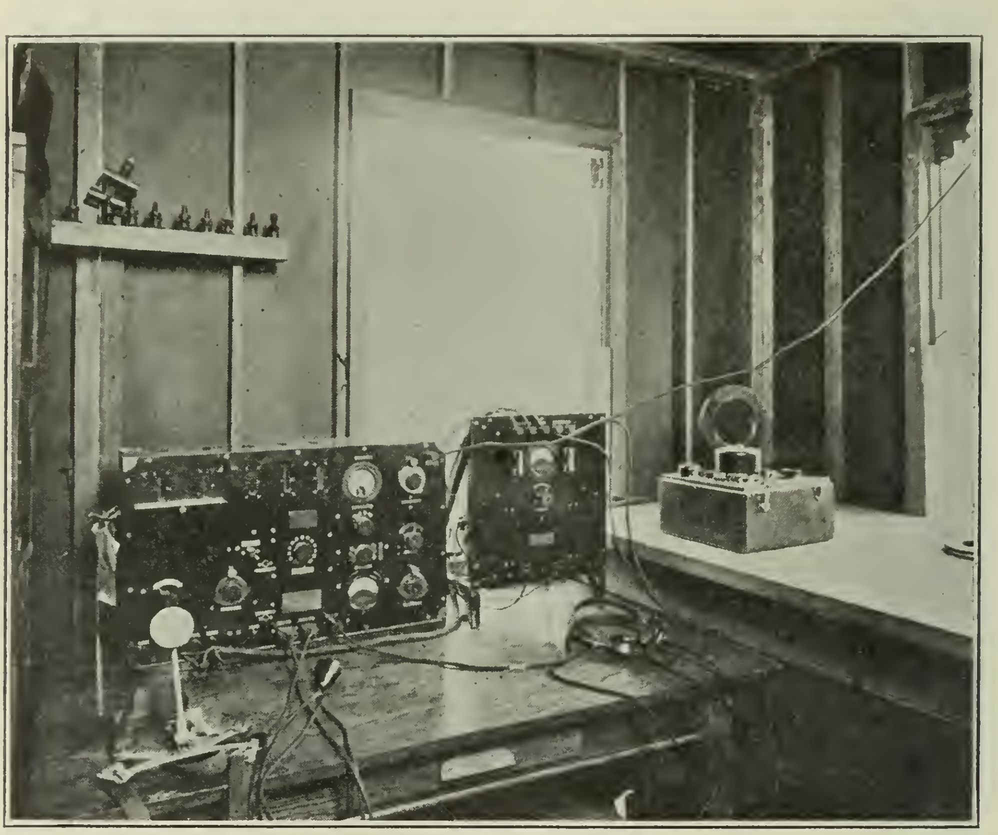
Floraphone long-wave receiving apparatus, with direction finder and "barrage" receiver.

"From this viewpoint, the general surface of the earth may be considered as supplied by nature with innumerable meteorological observation towers, which may be employed by means of apparatus involving principles already well known to science.

"In conclusion, it is believed that vegetation should be studied more systematically, from a distinctly physical standpoint than has been done in the past. Physics has been said to be the mother of all sciences, and more the physical method of studying all science is proving to be the true one, as is evidenced by the great advance in recent years, in comparatively new branches of scientific work, such as Astrophysics and Physical Chemistry. Has not the time arrived for a more systematic study of Physical Botany, in the light of the new electrical theory of matter?"

II. TREE ANTENNÆ.

In connection with the organization and development of Trans-atlantic radio reception which was carried out during the period of the war to provide against the possibility of the interruption of the submarine cable system, the Signal Corps established a chain of special receiving stations in different parts of the United States to copy and record enemy and allied radio messages from European stations for the information of our Army General Staff.



Floraphone radio telephone apparatus arranged for transmitting and receiving with tree antenna.

In the prosecution of this work, directions were given to the Signal Corps Laboratory at Camp Alfred Vail, Little Silver, New Jersey, and also to the experimental staff in Washington to test the efficiency of growing trees as receiving antennæ in connection with this service, using the vastly superior technic and facilities now represented in the radio art as compared with the crude apparatus with which the discovery was made in 1904. With a collection of apparatus representing the most advanced state of the radio art, the problem, as a war measure, was attacked anew and has now reached a point when a very brief outline of some of the physical results obtained should be presented in the interests of the development of the art in general. Since the phenomena involved embrace a variety of physical problems rather than strictly engineering ones, these data are presented to the Physical Society in the hope that some of its members may see in the experiments some points of departure for further research.

U. S. Signal Corps floraphone and floragraph laboratory and station, Grant Road, District of Columbia, April 18, 1919.

It was immediately discovered that with the sensitive amplifiers now in use it was possible to receive signals from the principal European stations by simply laying a small wire netting on the ground beneath the tree and connecting an insulated wire to a nail driven in the tree well within the outline of the tree top.

This encouraging first result justified a more careful examination of the phenomena and the most suitable arrangement of circuits for the purpose.

Without entering into the details of these preliminary experiments it may be said that one of the best receiving arrangements is found to be an elevated tree earth-terminal in the upper part of the tree top as described later, and an earth consisting practically of several short pieces of insulated wire sealed at the outer

"Floraphone," oak tree used as antenna.

ends radiating out from a common centre, and buried a few inches beneath the surface of the ground in the neighborhood of the tree.

It was soon found that a tree-antenna could be used efficiently as a multiple receiving set over widely different wave lengths, receiving either from separate terminals at the same or different heights of the tree or in series from the same terminal.

This same type of circuit was employed in an inverse manner for telephonic transmitting purposes, and although the experiments thus far have been limited to short distances, it was found that 2-way telephonic communication was easily established with remarkably low values of transmitting antenna current.

The flexibility of this arrangement is very striking. The linking up of wire and wireless methods was found to be convenient and efficient. Radio telephonic messages from airplanes were readily received by the tree-antenna arrangement and transferred thence to the wire system of the City of Washington and finally received at any point desired.

Furthermore, telephonic transmission through the tree-antenna was received by another tree-antenna, and automatically returned to the sender on a wire system, thus making the complete circuit. Long distance reception on any wave length from all the larger European stations and from our ships at sea was easily accomplished and traffic copied on a twenty-four-hour schedule by the regular enlisted operators of the Signal Corps. A small portable house serving as a field laboratory was erected in the midst of the forest area on Grant road, Washington, D. C., between the Bureau of Standards and Chevy Chase, Maryland, and here was assembled a collection of the most efficient vacuum tube amplifiers developed to date by the Signal Corps of the Army, the Navy, the British and the French, and of commercial firms in the United States. With these unusual facilities it was a matter of a few days to test out, at least in a superficial manner, a large number of proposed arrangements using trees as antennæ. Second Lieutenants H. A. Browning and M. C. Batsel, Signal Corps, have been in charge of this field laboratory.

The following data on the electrical constants of tree-antennæ have been obtained by Captain F. E. Pernot, Signal Corps, in charge of the Signal Corps radio research laboratory at the Bureau of Standards.

Physical Properties.

Early experiments performed by Lieutenant J. A. Riner and Lieutenant H. A. Browning, Signal Corps, served to ascertain the relation between the audibility of received signals and the height of the tree contact above the ground, but gave no data concerning the magnitudes of the electrical properties which characterized such an antenna system. It is the intention here to examine more closely into such properties.

The two quantities which serve to characterize an antenna system are (1) the apparent impedance of the antenna as measured at the particular frequency in question from the two terminals which lead to the receiving set, and (2) the electromotive force at these terminals when they are open-circuited and the intensity of the electromagnetic radiation impinging upon the antenna system is unity.

Antenna Impedance.

The antenna impedance Z depends upon the frequency for any given system, and consists of the two components, resistance and reactance, the latter usually being condensive. It is expressed in complex quantities as:

$$z = r - j\ x$$

$r =$ resistance in ohms

$$x = \frac{1}{2\pi f C} \text{ reactance in ohms}$$

r and x are to be taken as the equivalent series constants at frequency f. To distinguish these series constants from the constants of a parallel-connected system, having the same impedance, the following notation may be used:

$r_s =$ series resistance
$C_s =$ series capacity
$C_p =$ parallel capacity
$r_p =$ parallel resistance

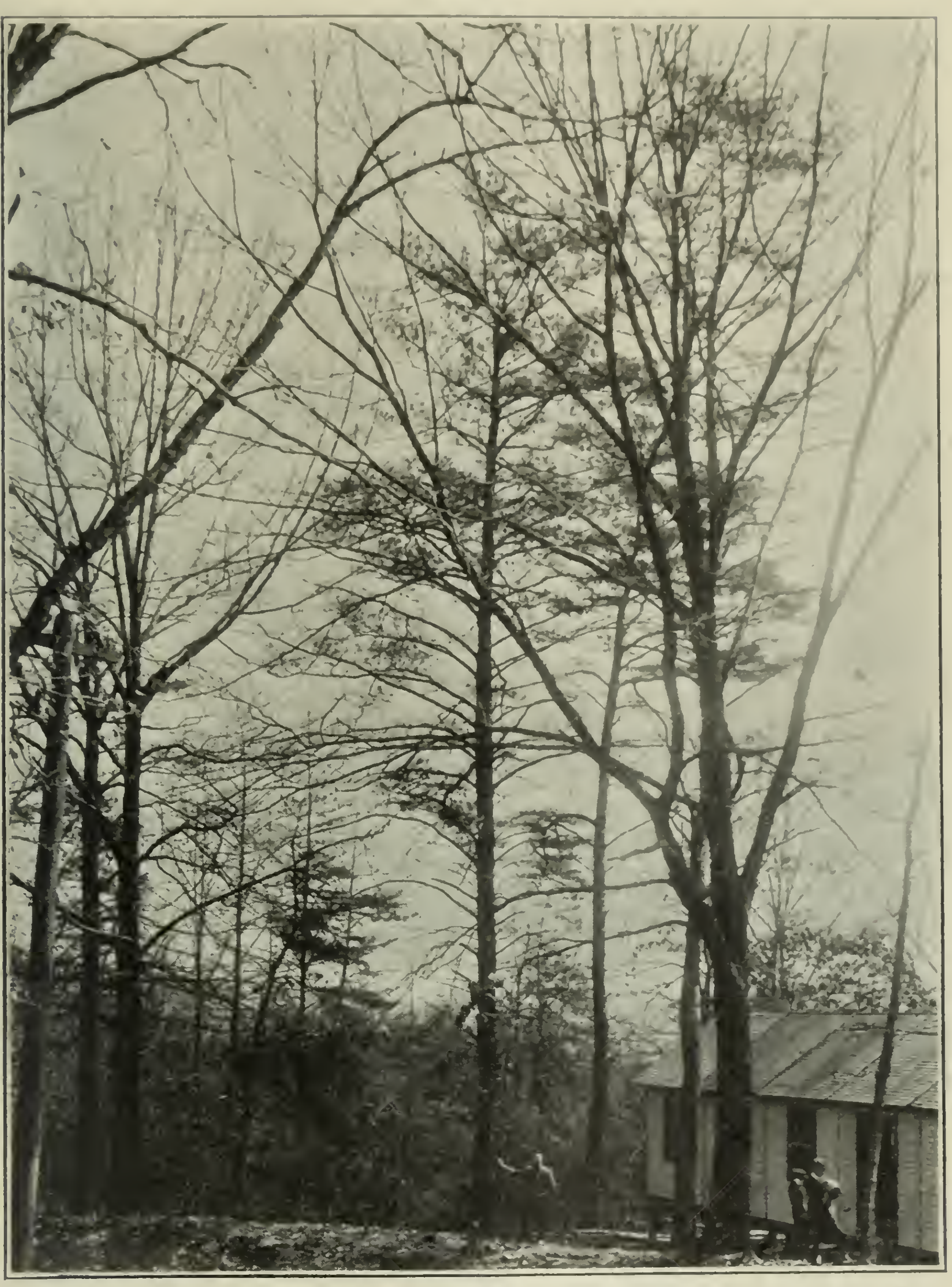
These quantities are related by

$$r_s = \frac{1}{1+(r_p \omega C_p)^2}\, r_p \quad \text{and} \quad C_s = \frac{1+(r_p \omega C_p)^2}{(r_p \omega C_p)^2}\, C_p$$
$$\text{where } \omega = 2\pi f$$

In some cases it is more convenient to determine the series capacity and resistance than the similar parallel quantities and *vice versa.* The above equations permit of ready conversion from one form to the other.

The following experiments were made on a pine tree shown in Plate I. The general location of the tree and its surroundings are shown in Plate II.

PLATE I.



Pine tree used in experiments. Average diameter about 25 cm. Signal Corps floraphone laboratory at the right.

Tree contact was made through copper nails driven three inches into the tree. Ground contact was made through a bundle of copper wire buried three feet deep in moist soil. Three grounds were installed so that the individual resistances could be determined. An average value for this resistance with direct current was 150 ohms. At radio frequencies, on account of capacity effects, this resistance was much smaller.

Using the substitution method, measurements of the apparent series capacity and resistance of the lead alone and of the lead attached to nails driven into the tree at various heights were made at different frequencies. In all cases the lead was of just sufficient length to reach to the point of contact, whether connected electrically to the nail or free.

Plate II.

Portion of surroundings of pine tree. Tree used indicated by arrow.

The original data are given in Tables I and II. From these data after cross-plotting to eliminate irregularities, consistent and regular families of curves, as shown in Figs. 1, 2, 3 and 4, were obtained. Wave lengths from 150 to 700 metres are covered.

The small change in the electrostatic capacity occasioned by making electrical contact with the tree, while all other conditions remain unaltered, is to be remarked and also the large increase in resistance under the same conditions. The increase in resistance is particularly pronounced for small heights and long wave lengths.

TABLE I.

Apparent Series Capacity and Resistance of Antenna Lead.

(Measured between ground and lower end of conductor, upper end of which reached to but was not connected with, a nail in the tree at height indicated. Substitution method of measurement.)

Height h metres.	Wave length λ metres.	Frequency f Cyc./sec.	Resistance r_s ohms.	Capacity C_s micro-micro-farads.
4.6	152	1,975,000	118	70
4.6	300	1,000,000	133	65
4.6	500	600,000	228	65
4.6	700	429,000	310	65
4.6	980	306,000	400	65
6.1	109	2,750,000	61	100
6.1	161	1,863,000	120	90
6.1	300	1,000,000	179	85
6.1	500	600,000	326	80
6.1	750	400,000	500	85
8.5	111	2,700,000	80	100
8.5	160	1,875,000	94	80
8.5	275	1,092,000	136	80
8.5	386	777,000	196	80
8.5	700	429,000	420	90
8.5	1,000	300,000	490	90
10.7	102	2,942,000	92	340
10.7	126	2,380,000	108	150
10.7	183	1,640,000	128	120
10.7	280	1,074,000	206	110
10.7	380	789,000	290	110
10.7	480	625,000	390	100
10.7	805	373,000	710	110
10.7	905	331,000	820	110
12.2	100	3,000,000	290	210
12.2	130	2,308,000	109	150
12.2	186	1,615,000	160	120
12.2	288	1,042,000	270	110
12.2	435	690,000	386	110
12.2	635	472,000	680	110
12.2	810	370,000	600?	100
12.2	810	370,000	860	100
14.0	110	2,727,000	65	440
14.0	147	2,041,000	100	190
14.0	198	1,516,000	140	152
14.0	304	987,000	209	148
14.0	445	674,000	330	145
14.0	880	341,000	710	148
17.4	127	2,360,000	67	570
17.4	164	1,829,000	92	240
17.4	220	1,364,000	121	200
17.4	340	883,000	182	180
17.4	485	618,000	276	174
17.4	787	382,000	450	190
17.4	870	345,000	517	185

TABLE II.

Apparent Series Capacity and Resistance of Antenna Lead Connected to the Tree.

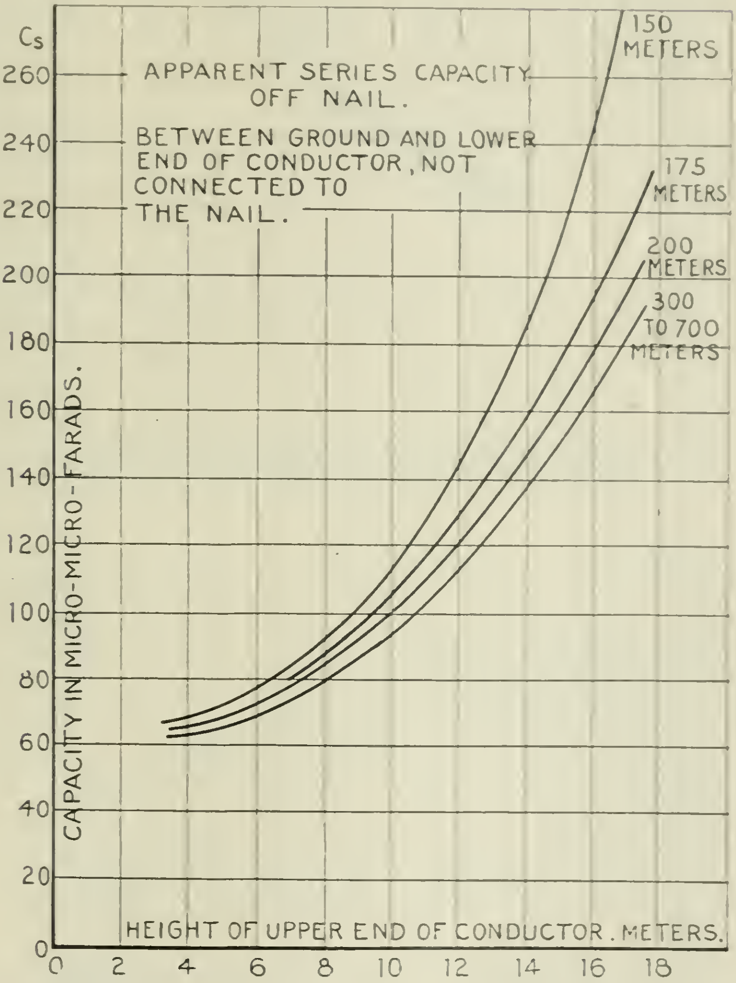
(Measured between ground and lower end of conductor connected to a nail in the tree at the height indicated. Substitution method of measurement.)

Height h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance r_s ohms.	Capacity C_s micro-micro-farads.
4.6	103	2,910,000	248	90
4.6	107	2,800,000	122	90
4.6	153	1,962,000	211	85
4.6	235	1,276,000	300	85
4.6	354	847,000	440	85
4.6	595	504,000	1,110	85
4.6	650	462,000	1,290	85
4.6	885	339,000	2,050	70
6.1	117	2,563,000	123	115
6.1	165	1,820,000	202	95
6.1	260	1,154,000	317	90
6.1	382	786,000	660	90
6.1	440	682,000	625	95
6.1	500	600,000	85?	105
6.1	525	572,000	820	105
6.1	550	546,000	910	135
6.1	745	403,000	1,260	130
6.1	800	375,000	1,590	100
8.5	103	2,910,000	230	205
8.5	113	2,653,000	192	110
8.5	156	1,923,000	245	85
8.5	280	1,072,000	418	90
8.5	395	760,000	665	95
8.5	700	428,000	1,500	110
10.7	102	2,940,000	220	110
10.7	137	2,190,000	118	160
10.7	190	1,579,000	165	130
10.7	290	1,034,000	286	120
10.7	346	868,000	384	120
10.7	500	600,000	630	130
10.7	800	375,000	1,160	140
12.2	102	2,940,000	210	670
12.2	133	2,250,000	127	150
12.2	185	1,622,000	196	130
12.2	288	1,042,000	325	110
12.2	415	722,500	553	120
12.2	690	434,000	1,060	130
12.2	740	405,500	1,150	130
14.0	108	2,780,000	144	780
14.0	144	2,083,000	130	203
14.0	200	1,500,000	170	163
14.0	312	961,000	280	148
14.0	445	675,000	476	145
14.0	805	372,000	980	150
14.0	835	359,000	980	166

TABLE II.—*Continued.*

Height h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance r_s ohms.	Capacity C_s micro-micro-farads.
17.4	130	2,309,000	66	640
17.4	165	1,820,000	109	260
17.4	220	1,360,000	134	200
17.4	343	873,000	200	185
17.4	490	612,500	325	180
17.4	870	344,000	596	181
17.4	875	343,000	606	185
17.4	925	323,700	670	180

FIG. 1.



It is interesting to note that no correspondence is to be observed between the resistance curves, as determined by these measurements, and the curves representing the radiation resistance of

FIG. 2.

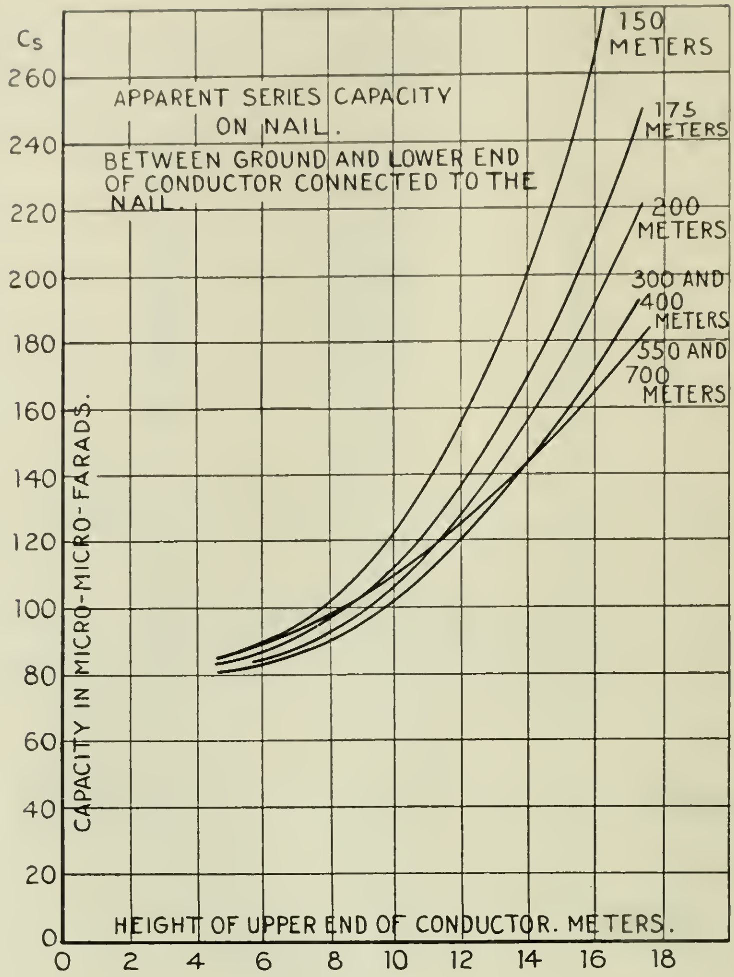
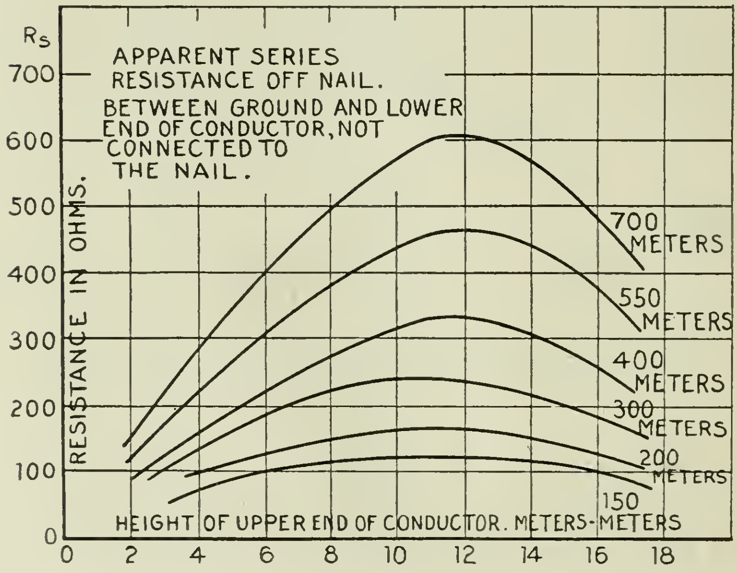

Cs
APPARENT SERIES CAPACITY ON NAIL.
BETWEEN GROUND AND LOWER END OF CONDUCTOR CONNECTED TO THE NAIL.
CAPACITY IN MICRO-MICRO-FARADS.
HEIGHT OF UPPER END OF CONDUCTOR. METERS.
150 METERS
175 METERS
200 METERS
300 AND 400 METERS
550 AND 700 METERS
0
20
40
60
80
100
120
140
160
180
200
220
240
260
0
2
4
6
8
10
12
14
16
18

FIG. 3.


Rs
APPARENT SERIES RESISTANCE OFF NAIL.
BETWEEN GROUND AND LOWER END OF CONDUCTOR, NOT CONNECTED TO THE NAIL.
RESISTANCE IN OHMS.
HEIGHT OF UPPER END OF CONDUCTOR. METERS-METERS
700 METERS
550 METERS
400 METERS
300 METERS
200 METERS
150
0
100
200
300
400
500
600
700
0
2
4
6
8
10
12
14
16
18

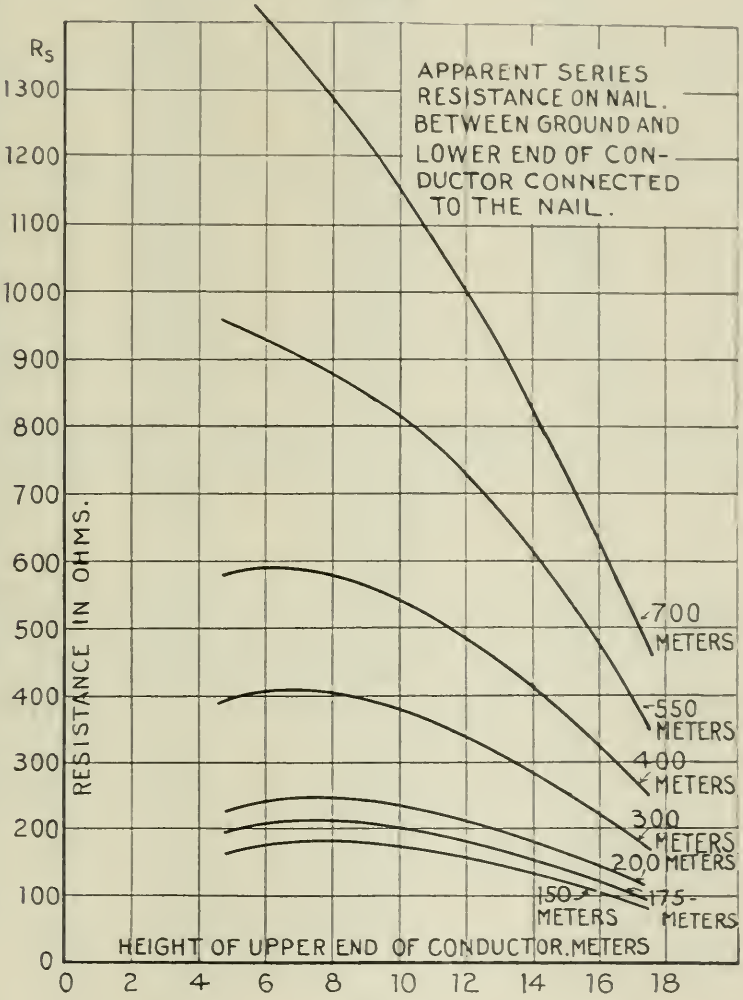
a simple vertical wire. The latter curves are parabolas (as functions of the height) given by the equation:

$$\text{Radiation resistance} = 400\left(\frac{h}{\lambda}\right)^2$$

where h = height of vertical wire
λ = wave length.

The coefficient in this equation is based upon a form factor of approximately ½ corresponding to values of λ large in comparison with $4h$. (See Zenneck, "Wireless Telegraphy," page 170.)

FIG. 4.



The explanation of such large resistance values in case of tree antennæ is probably to be found in the effect of the immediate proximity of partially conducting media to the conducting lead.

For long waves (low frequencies) the substitution method was not found satisfactory, so another method, in which the

TABLE III.

Apparent Resistance and Capacity Considered as Elements in Parallel.

(Measured between ground and lower end of conductor attached to a nail in the tree at the height indicated. Measured by shunting the antenna system around a known condenser and noting the change in resistance and capacity of the circuit caused thereby.)

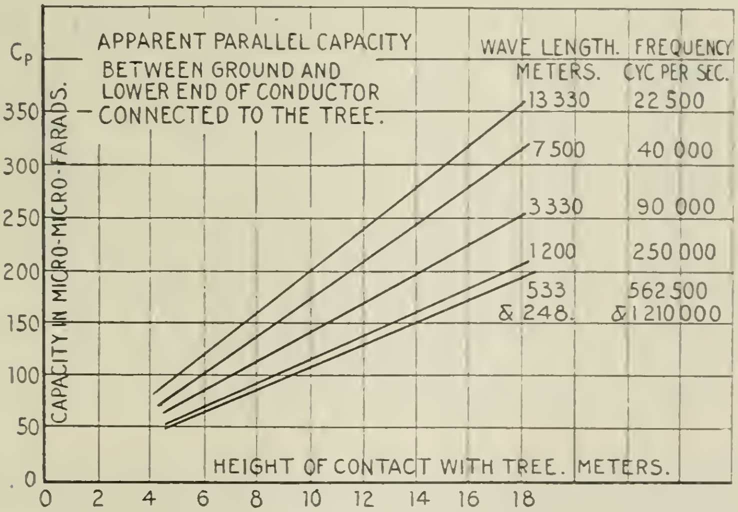
Height of contact h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance shunt r_p ohms.	Capacity shunt C_p micro-micro-farads.
Direct current resistance with ohmmeter = 38,000 ohms.				
4.6	250	1,200,000	7,910	45.5
4.6	500	600,000	15,780	61.8
4.6	1,000	300,000	16,909	71.5
4.6	2,000	150,000	21,220	71.5
4.6	3,500	85,700	24,900	87.8
4.6	5,000	60,000	26,220	87.8
4.6	10,000	30,000	26,800	87.8
4.6	19,700	15,200	27,900	81.3
Direct current resistance with ohmmeter = 39,000 ohms.				
6.1	250	1,200,000	4,675	74.8
6.1	500	600,000	10,900	71.5
6.1	1,000	300,000	11,080	84.5
6.1	2,000	150,000	11,510	81.3
6.1	3,500	85,700	16,650	133.3
6.1	5,000	60,000	17,850	104.0
6.1	10,000	30,000	18,500	120,5
6.1	19,700	15,200	19,230	325.0
Direct current resistance with ohmmeter = 37,500 ohms.				
8.5	250	1,200,000	3,350	84.5
8.5	500	600,000	7,730	94.2
8.5	1,000	300,000	8,080	58.5
8.5	2,000	150,000	10,400	87.8
8.5	3,500	85,700	12,520	123.5
8.5	5,000	60,000	13,220	136.5
8.5	10,000	30,000	14,191	188.5
8.5	19,700	15,200	15,420	162.5
Direct current resistance with ohmmeter = 44,000 ohms.				
10.7	250	1,200,000	2,540	110.5
10.7	500	600,000	7,090	110.5
10.7	1,000	300,000	8,090	113.7
10.7	2,000	150,000	10,720	113.7
10.7	3,500	85,700	13,140	130.0
10.7	5,000	60,000	14,090	162.5
10.7	10,000	30,000	15,500	191.7
10.7	19,700	15,200	17,050	195.0
Direct current resistance with ohmmeter = 50,000 ohms.				
12.2	250	1,200,000	1,980	156.0
12.2	500	600,000	6,250	133.3
12.2	1,000	300,000	7,180	139.7
12.2	2,000	150,000	12,780	149.5
12.2	3,500	85,700	12,080	191.8
12.2	5,000	60,000	13,320	211.2
12.2	10,000	30,000	15,180	273.0
12.2	19,700	15,200	17,670	325.0

TABLE III.—*Continued.*

Height of contact h metres.	Wave length λ metres.	Frequency f cyc./sec.	Resistance shunt r_p ohms.	Capacity shunt C_p micro-micro-farads.
Direct current resistance with ohmmeter = 60,000 ohms.				
14.0	250	1,200,000	1,920	159.2
14.0	500	600,000	4,600	159.2
14.0	1,000	300,000	7,530	175.5
14.0	2,000	150,000	10,490	172.2
14.0	3,500	85,700	13,480	188.5
14.0	5,000	60,000	15,180	227.5
14.0	10,000	30,000	17,720	270.0
14.0	19,700	15,200	20,900	390.0
Direct current resistance with ohmmeter = 105,000 ohms.				
17.4	250	1,200,000	2,180	172.2
17.4	500	600,000	6,780	172.2
17.4	1,000	300,000	16,330	195.0
17.4	2,000	150,000	16,420	214.5
17.4	3,500	85,700	23,190	234.0
17.4	5,000	60,000	27,900	247.0
17.4	5,000	60,000	29,500	247.0
17.4	10,000	30,000	38,200	302.2
17.4	19,700	15,200	47,400	325.0

antenna of unknown properties was shunted around a condenser which constituted a portion of a resonant circuit, was used. This method of measurement yields the apparent values of the antenna constants when they are considered as elements in parallel.

FIG. 5.



Original data so obtained are shown in Table III. For these data the antenna lead was connected to the tree, and from it, after closs-plotting to eliminate accidental errors, the curves shown in Figs. 5 and 6 were obtained. The apparent capacity curves in Fig. 5 are instructive, indicating, as they do, a capacity proportional to the height of contact.

FIG. 6.

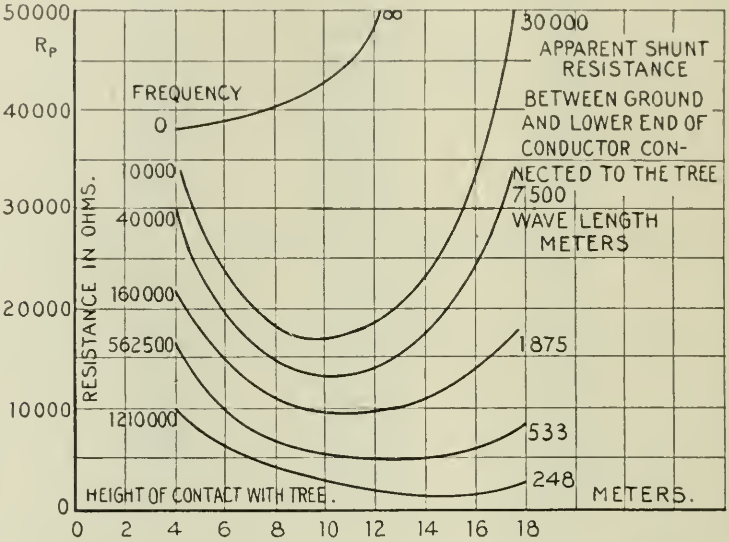
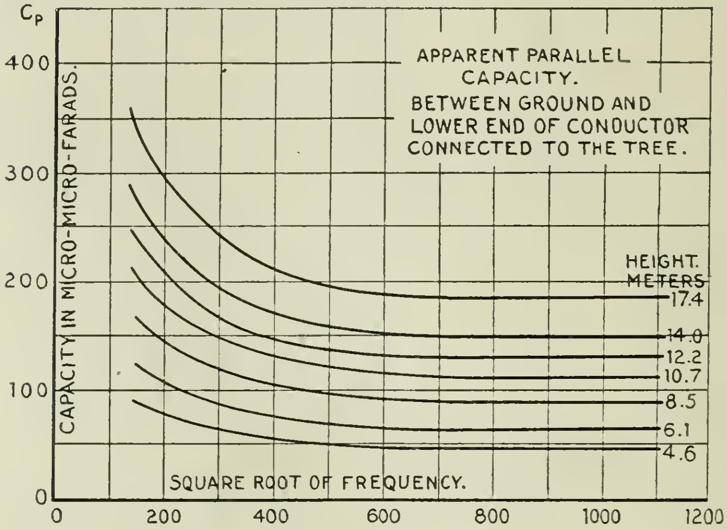


FIG. 7.



Besides showing capacity and resistance as functions of height of contact, they may also be plotted as functions of frequency, or, as happens to be more convenient in this case, the square root of frequency. Such curves are shown in Figs. 7 and 8. Taking a number of representative points from these curves of apparent shunt characteristics, the values of the equivalent series characteristics were calculated by the aid of the equations previously given. The data given in Table IV and shown plotted in Figs. 9 and 10 were thus obtained.

FIG. 8.

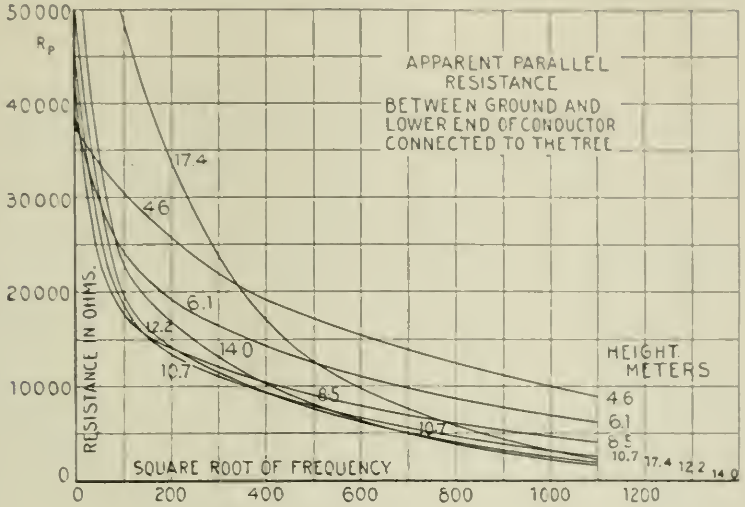


TABLE IV.

Apparent Resistance and Capacity Considered as Elements in Series.

(Calculated from data taken from the curves in Figs. 7 and 8.)

C_s = Capacity in micro-micro-farads.

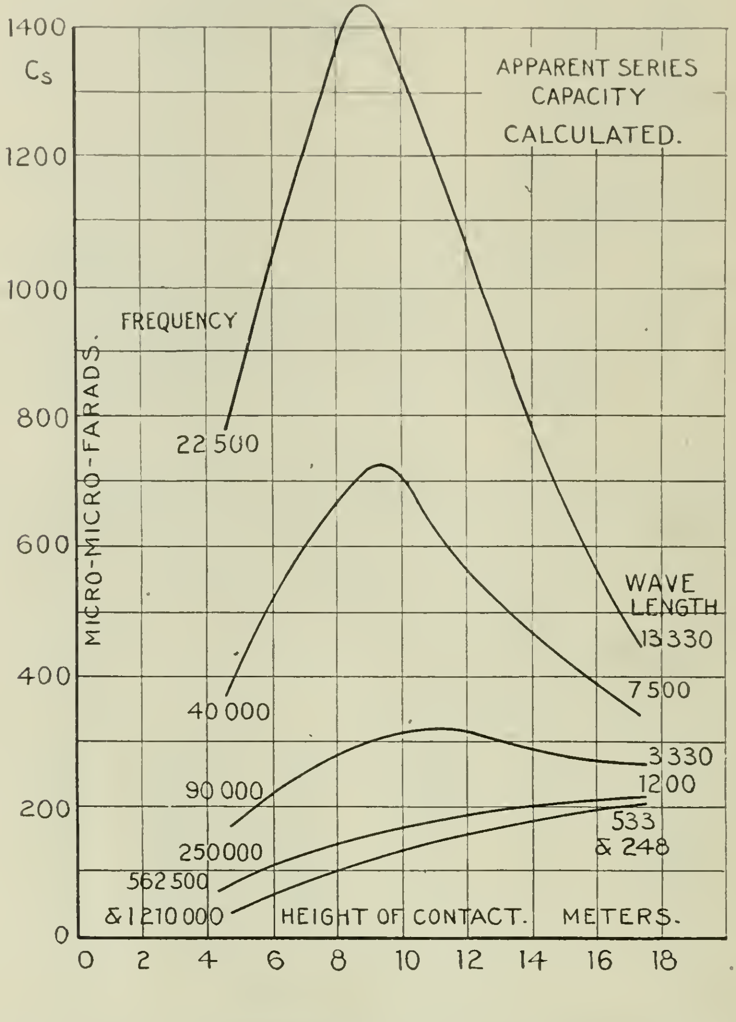
Frequency f.	Height in metres, h.						
	4.6	6.1	8.5	10.7	12.2	14.0	17.4
22,500	794	1,031	1,465	1,212	1,044	763	432
40,000	380	510	699	658	575	471	346
90,000	162	220	299	320	309	285	264
250,000	78	107	148	173	189	197	210
562,500	59	80	112	142	161	177	197
1,210,000	54	73	103	139	168	195	206

r_s = Resistance in ohms.

Frequency f.	Height in metres, h.						
	4.6	6.1	8.5	10.7	12.2	14.0	17.4
22,500	24,900	18,900	13,500	12,700	12,400	12,300	8,300
40,000	20,400	15,300	11,100	9,700	9,200	8,300	4,500
90,000	13,500	10,100	7,320	5,960	5,210	4,250	2,060
250,000	5,780	4,330	3,170	2,410	2,040	1,580	770
562,500	2,130	1,640	1,220	960	840	680	330
1,210,000	750	590	460	430	420	370	200

Certain portions of the curves in Figs. 7 and 8 and of those in Figs. 2 and 4, overlap and therefore the results may be compared. Such a comparison indicates some discrepancies, but these may be explained by the fact that the measurements were made at different dates and after the tree had undergone widely different weather conditions.

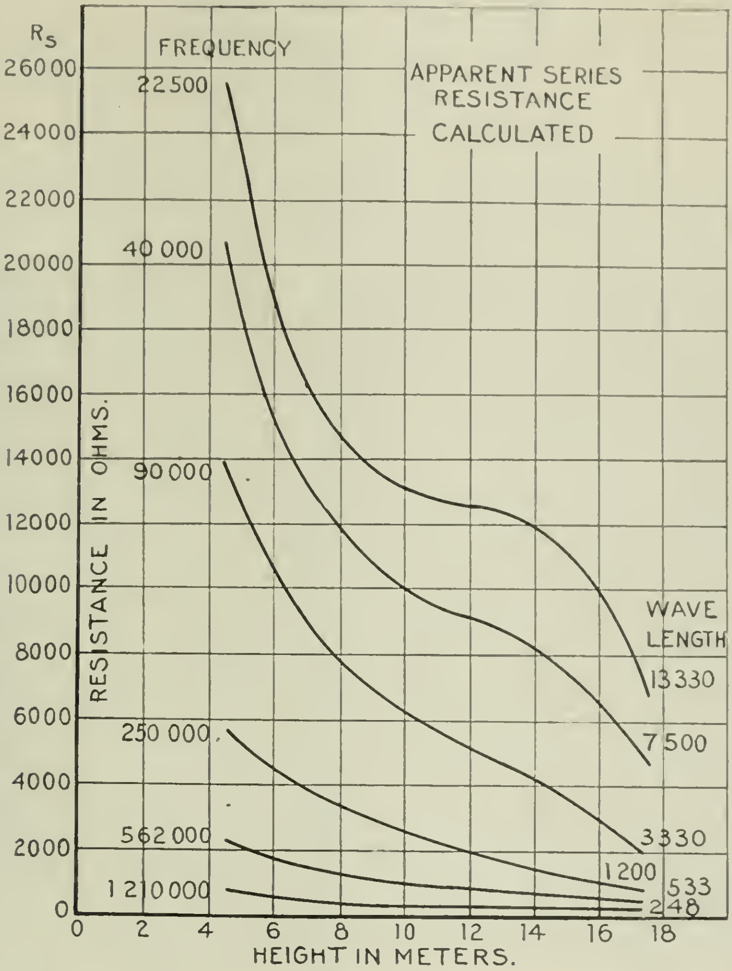
FIG. 9.



Referring to the general theory of alternating current systems it can be shown that the receiver constants for which a maximum energy extraction from the antenna is obtained are: (1) The receiver inductance should be such as to resonate with the apparent antenna capacity at the frequency in question. (2) An effective receiver resistance equal to the apparent resistance of the antenna at the frequency in question.

An inspection of the foregoing curves shows that, in general, the effective antenna resistance is many times the apparent resistance of antennæ as ordinarily used, and that, therefore, the design of receivers should be materially altered in order to utilize to the best advantage the energy impinging upon the tree in the form of electromagnetic radiation. Except for very weak signals, however, it is not necessary to utilize this energy to the fullest extent, so that receivers of present design may be used, and when so used, are responsive to any wave length of radiation.

FIG. 10.



Open-circuit Voltage.

The other quantity which serves to determine the characteristics of any antenna system as a receiver of electromagnetic radiation from a given sending station is the open-circuit electromotive force E. The determination of this quantity by measurement is a matter of considerable difficulty and so far has not been accomplished with reference to the particular problem in hand. Apparatus of sufficient sensitiveness to accomplish the direct measurement of this electromotive force is not at present available to the art. Indirect methods may, however, be used,

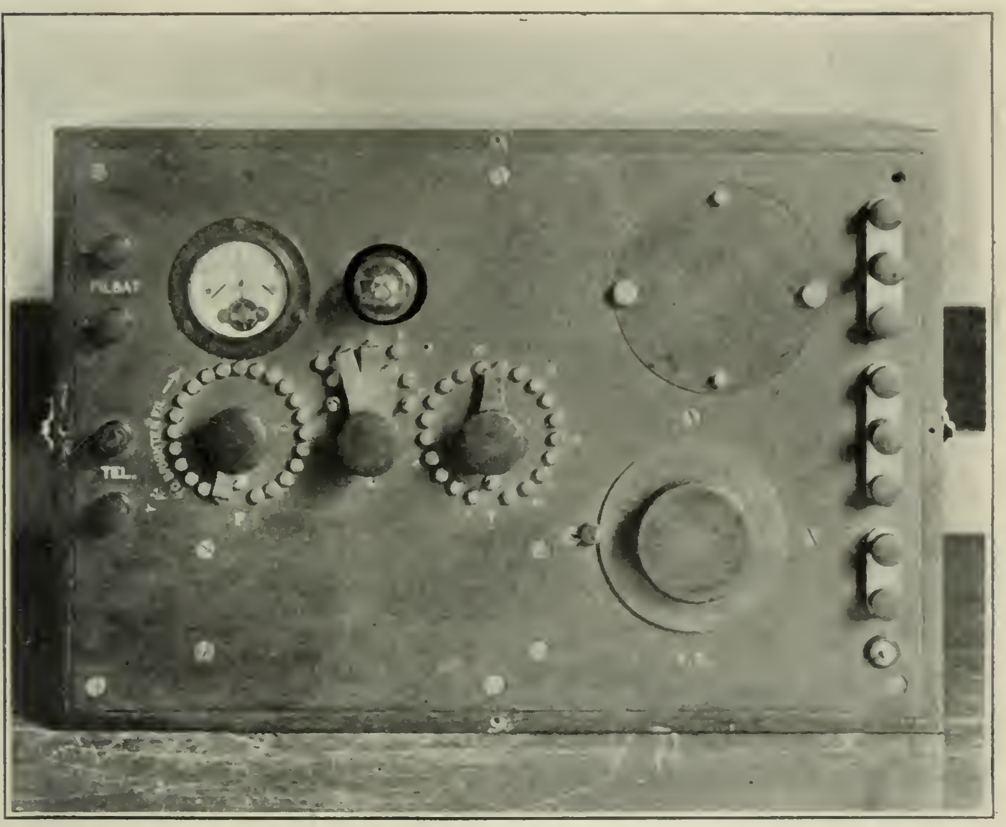
PLATE III.

Large poplar tree used in audibility measurements. Average diameter 0.33 meters.

and from them comparative results of fair accuracy may be expected. An outline of one such indirect method is given here.

The open-circuit voltage of the tree system as an antenna is to be determined for different heights of contact and for different frequencies. To be of use in determining the behavior of the antenna system, without reference to a particular sending station, this open-circuit voltage must be that for unit field strength of impinging radiation. This can be determined by dividing the observed value of voltage by the calculated field strength set up by the particular sending antenna.

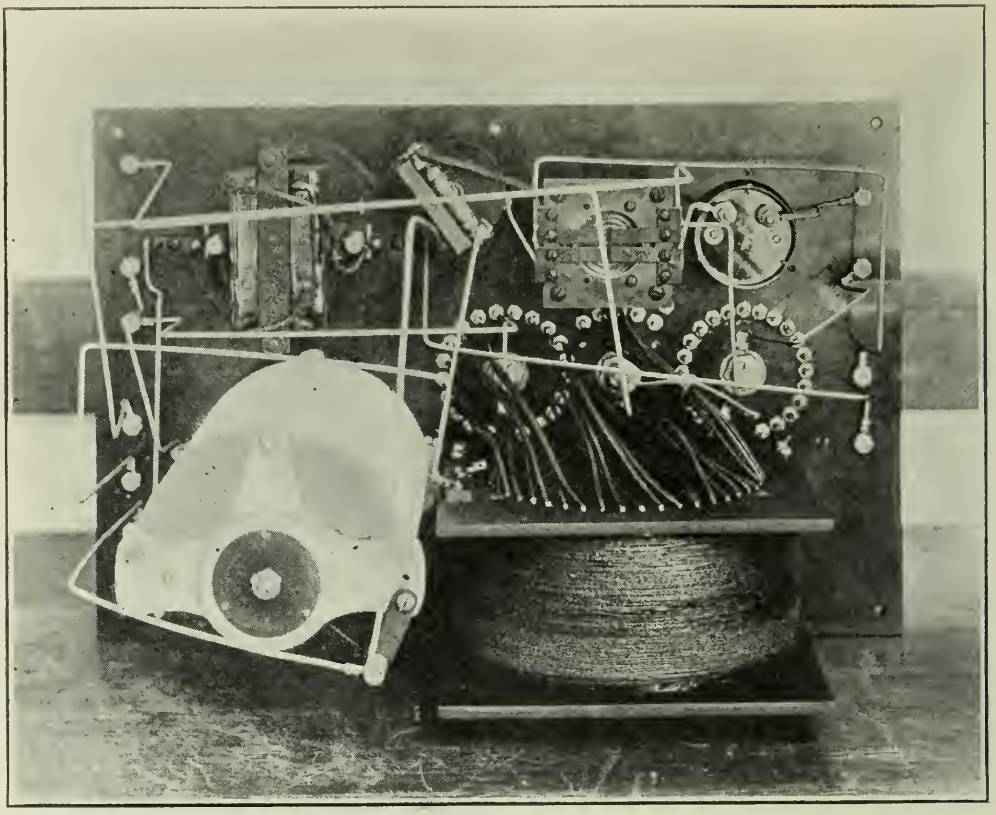
PLATE IV.



Front view of Signal Corps portable heterodyne receiver used for audibility measurements.

To make observations a simple form of antenna for which the open-circuit voltage can be calculated in terms of the field strength may be used, such as a simple vertical wire. After the apparent properties at the various frequencies which are to be used have been determined, connect in series with this antenna (also shunting it by a capacity to ground if necessary) such resistance and capacity as to make its total constants equal to the apparent constants of the antenna whose open-circuit voltage is desired. Then arrange for the alternate connection of these two antenna systems to a receiving set and associated audibility meter. The readings of the audibility meter which give equal intensity of signals then correspond approximately to the square of the open-circuit voltages (Austin's Law for a Vacuum Tube Rectifier using a grid leak and a condenser). The open-circuit voltage of the simple antenna being calculable, the value of the voltage for the unknown system becomes known. If it is desired to eliminate from the calculations this law concerning rectification, the antenna may be loosely coupled to the receiving set and the coupling varied for the two systems until equal signals are received, thus eliminating the audibility meter—a device not at present very dependable. For equal signals the ratio of such coupling is inversely proportional to the open-circut electromotive force because of the fact that the

PLATE V.

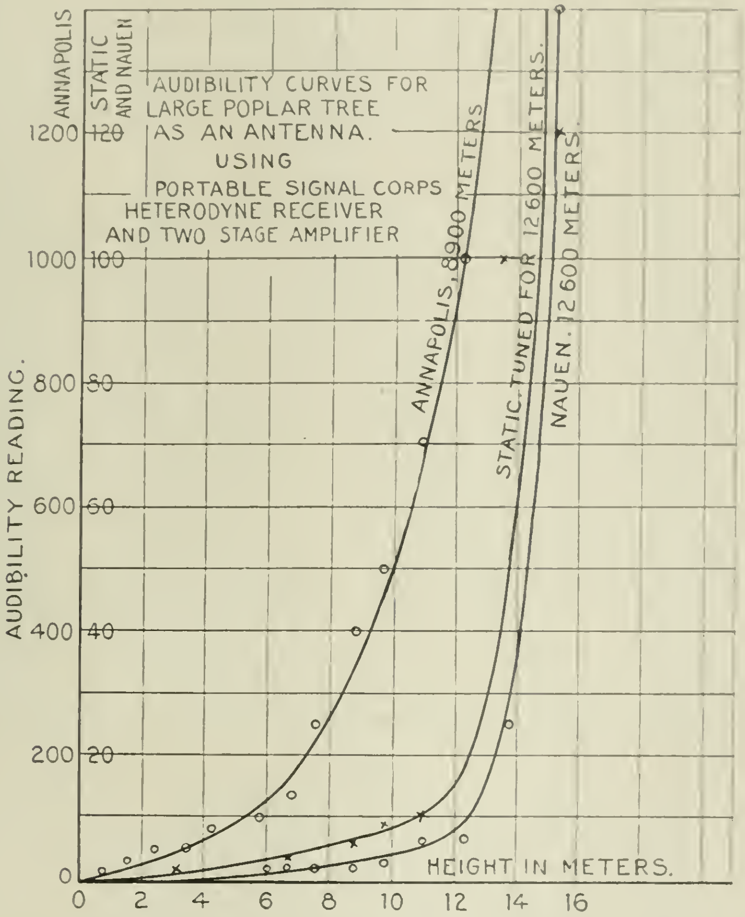


View of interior of Signal Corps portable heterodyne receiver used for audibility measurements.

impedances of the two antenna systems were originally made equal.

From the field experiments made by Lieutenant Browning and Lieutenant Riner, Signal Corps, certain data are available giving the audibility of signals as received with a portable Signal Corps Heterodyne Receiver and two-stage amplifier connected to a large poplar tree as an antenna. Plate III shows the tree used. Plates IV and V show the receiving set.

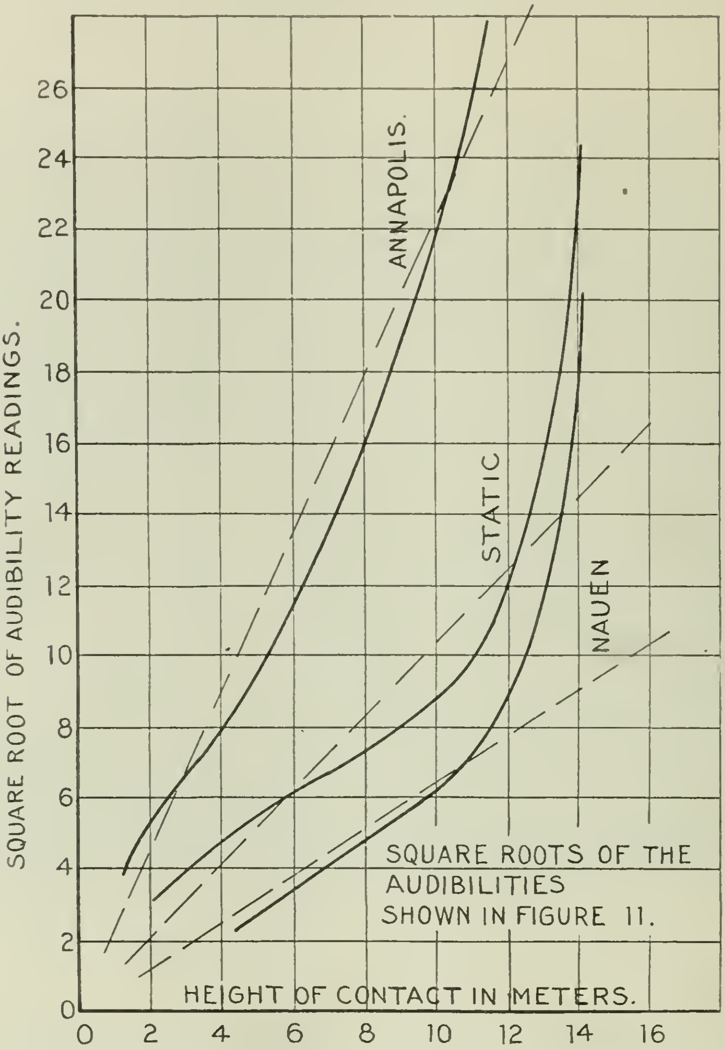
FIG. 11.



With the receiving set tuned to give the best signal strengths, data concerning the audibilities at different heights of contact were obtained. These data are illustrated by Fig. 11, in which audibilities are shown as functions of the height of contact. The wave lengths are indicated on the curves. Very great increase in audibility occurs at about twelve metres height (about two-thirds of the total height of the tree).

Since the audibilities are approximately proportional to the square of the electromotive force applied to the receiving set used at a given frequency, it is instructive to consider the curves showing the square roots of the audibilities. Such curves are shown in Fig. 12, and, except for values above twelve metres in height, these curves are quite closely approximated by straight lines. Theory would lead to the conclusion that the open-circuit voltage is a straight-line function of the height, and, since the receiving set was tuned to maximum sensitiveness for each reading so that the total reactance of the circuit was zero, the remaining quantity to which must be attributed the departure of these curves from straight lines is the variable (and in this case unknown) antenna resistance. In other words, it is suggested

Fig. 12.



that, had the total resistance of the antenna system been maintained constant by the insertion of series resistance of the proper value, the curves in Fig. 12 would approximate very closely to straight lines.

The trees on which the impedance measurements and the audibility measurements were made are practically equal in height, so that it is reasonable to suppose that similar phenomena would be observed in both. It is to be noted that the height at which the audibility curves show their sharpest upward trend, which is also the same height for which the square roots of the audibilities depart from the straight-line relation, is also the height at which the apparent shunt resistance r_p reaches a minimum value in Fig. 6, for the wave lengths involved in the audibility measurements.

Although the term " open-circuit voltage " has been introduced throughout the foregoing discussion, it will be well to recognize the fact that such a means of specification of an antenna's properties corresponds closely to means of expression already in use, that is to the " effective height." This effective height is proportional to the open-circuit electromotive force for unit field intensity. It is usually considered as the height of the centre of the antenna capacity above the ground plane. It is only in order to lead to a clear conception of any antenna system as a particular form of the general electrical circuit that the term " open-circuit voltage " has been introduced.

It is hoped to determine more definitely in the future, by some such method as has been outlined, the exact relation between the geometry of the tree system and the open-circuit voltage.

GONIOMETRIC METHODS APPLIED TO TREE ANTENNÆ.

One of the special lines of radio development caused by the war has been the application of radio methods to direction finding for military purposes. The Signal Corps has evolved and standardized certain sets possessing extreme compactness for the use of the mobile forces.

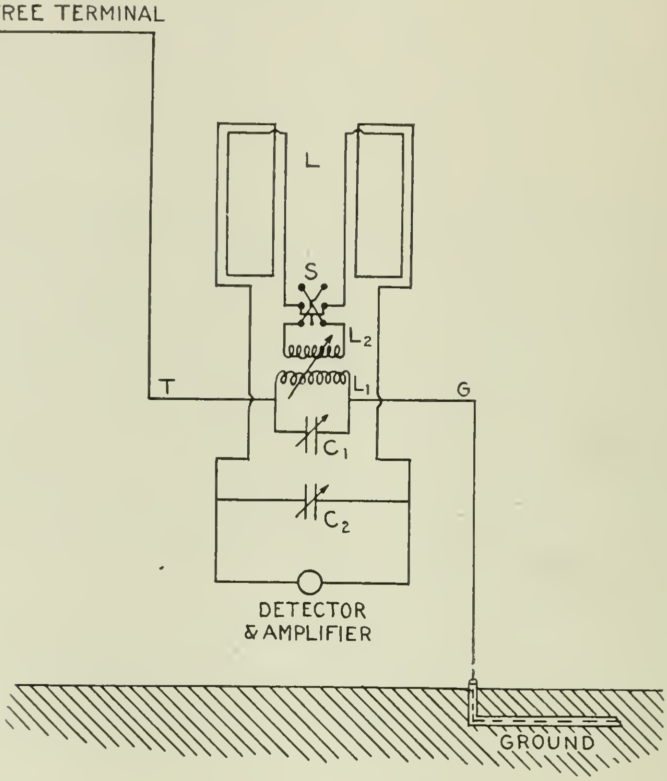
Under the intensive study of this subject, stimulated by the war, a large amount of technical information has been obtained which is now available for use and application to the purposes of peace.

Through the coöperation of F. A. Kolster of the Bureau of

Standards, who has specialized in this work for the Navy Department, some applications of these methods have been applied to tree antennæ.

Coil aerials of extremely small dimensions as compared with ordinary antennæ, may be effectively used for both long and short-wave long distance reception. It is therefore entirely possible to make use of such a coil aerial in combination with the tree system, without in any way detracting from the remarkable simplicity of the tree system, for the purpose of obtaining the desirable feature of unidirectional reception or so-called "barrage" effect.

FIG. 13.



Coil aerials of very small dimensions as compared with the wave length received are nothing more nor less than ordinary inductance coils directly and magnetically exposed to the incoming electromagnetic wave, and may form the entire or the major portion of the inductance of a simple series resonant circuit. Such a circuit is shown in Fig. 13, consisting of the coil aerial L, the inductance L_2, and the capacity C_2. This circuit to which there is connected the detector and amplifier forms the secondary receiving circuit of the system and is coupled inductively to the primary circuit L_1C_1 to which the tree and ground wires are connected at T and G.

The system is unique in that both primary and secondary circuits are directly exposed to the incoming wave. It is by virtue of this double exposure that the unidirectional characteristic of the system is obtained. In other words, both primary and secondary circuits are simultaneously operated upon by the incoming electromagnetic wave and by the proper adjustment of the linking coils L_1 and L_2, the effects produced in the secondary circuit may be entirely neutralized or accumulated. Switch S shown in Fig 13 is a reversing switch connected to coil L_2 which controls this neutralizing or accumulating effect.

Complete " barrage " effect was obtained with this system on stations such as New Brunswick, New Jersey; Annapolis, Maryland; Nauen, Germany, etc. This makes it possible, for example, to receive signals from San Diego, California, while the New Brunswick station is operating and using practically the same wave length as the San Diego station.

The coil aerials used in the experiments made with the system above described are but four feet square and therefore are located within the station, merely forming a part of the internal receiving apparatus and in no way complicating the simple tree system.

We have then a simple two-circuit receiving system requiring no extensive and costly outside aerial structure and have the following modern features:

a. Long distance reception at any wave length.
b. Direction finder giving not only the line of direction but the absolute direction.
c. Elimination of interference by virtue of the unidirectional characteristic or " barrage " effect.
d. Simultaneous reception of two or more wave lengths or of two similar wave lengths coming from opposite directions.

Heretofore, in existing operating stations the receiving circuits, of whatever nature, have operated primarily on the generation of alternating currents in the receiving antenna system, and because of this it has been necessary to tune the antenna system itself to the particular frequency of the signals. In the experiments in tree telephony and telegraphy, we may rather consider that we employ an aperiodic system in the form of the tree itself, and make use of the resultant potential effects at the upper tree terminal of this antenna, selecting from this reservoir of all frequencies the particular frequency desired, by means of external receiving devices now known to the art.

In addition to the plates already described a number of others are included which show in a general way the equipment and apparatus used.

III. AFTERWORD.

Potential Earth-Terminal.—We may regard the metallic electrode rigidly driven into the living organisms of a tree, as described above, as a potential earth-terminal for the study of the potential distribution on the surface of the earth itself. It has been shown in these experiments that this metallic terminal intimately connected to the earth itself and a part thereof is subject to changes of potential representing the innumerable frequencies required by modern radio telephony and telegraphy as well as any other electrical disturbances which may occur on the surface of the earth or the atmosphere above the earth.

It has been also shown, as expected, that we can select from this composite one or more of the different frequencies by tuned electrical loop circuits suitably connected to this electrode and study each in turn at will just as color screens can select a particular component of white light. We may, indeed, by means of a highly insulated conductor bring this terminal directly to the laboratory and connect it immediately to the modern thermionic tube and amplify almost at will the particular effects we are studying. This tube is a powerful and new instrument of research for the modern physical laboratory. Has not the physicist therefore in this electrode a means of studying in detail atmospheric and earth electrical disturbances of absorbing interest and far-reaching importance?

In short, the radio art as a whole has attracted some of the best equipped physicists in each country as perhaps no other practical engineering subject of recent years has done, with the result that the methods and means of the radio art are now immediately applicable and available to the physical laboratory for the study of the fundamental problems of the earth itself as a charged sphere.

For four years, under the stimulus of the World War, the efforts of engineers have been expended in producing instrumentalities for the generation and reception of radio signals and there has been little time to coördinate and assimilate the information gained into a better understanding of the ether mechanism for the transmission of electromagnetic waves through space, over the surface, or through the earth itself.

In the language of the modern captain of industry, physical theory is a temporary "corporation policy" rather than a fixed creed. Nevertheless, the modern specialist in science has, from the very nature of his intensive efforts, assumed what might be called a "polarized" attitude of mind toward the particular problem in hand.

The physicist and engineer, accustomed to deal with inanimate material, is here confronted with the employment of living vegetable organisms of growing trees. From the moment an acorn is planted in fertile soil, it becomes a "detector" and a "receiver" of electromagnetic waves and the marvelous properties of this receiver, through agencies at present entirely hidden from us, are such as to vitalize the acorn and to produce in time the giant oak. In the power of multiplying plant cells, it may, indeed, be called an incomparable "amplifier."

From this angle of view, we may consider that trees have been pieces of electrical apparatus from their beginning and with their manifold chains of living cells are absorbers, conductors, and radiators of the long electromagnetic waves as used in the radio art. For our present purposes we may consider, therefore, a growing tree as a highly organized piece of living earth to be used in the same manner as we now use the earth as a universal conductor for telephony and telegraphy and other electrical purposes.

All through the ages there is shown in literature a feeling of reverence, sympathy and human intimacy with trees. It is significant that this practical thing possessing utility and natural strength, architectural beauty of design, and endurance far superior to artificial structures prepared by man, should be able yet further to minister to his needs.

WAR DEPARTMENT, WASHINGTON, D. C.,
Office Chief Signal Officer,
April 21, 1919.

Cadmium a Substitute for Tin in Solders. ANON. (*U. S. Geological Survey Press Bulletin No. 407,* May, 1919.)—The large quantity of tin used in making food containers for rationing the American and Allied armies, combined with the lack of shipping and the loss of several cargoes of tin, produced a critical scarcity of tin in this country and led to government control of its distribution as well as to a campaign for its conservation. One method of saving tin is to substitute cadmium for it in solder. In the last year of the war the government and certain large concerns began experiments with cadmium solders as a means of saving tin. The results of these experiments were promising, but the demand for tin decreased, and the armistice was signed before cadmium solders became widely used. Cadmium was used by European nations during the war for some strictly military purposes, but little exact information is available to show those purposes.

The first of the belligerent nations to make large use of cadmium as a substitute for tin in solders was Germany, which from the beginning of the war was cut off by the blockade almost entirely from the world's sources of tin. About 600 tons of cadmium accumulates annually in this country as dusts and residues, by-products of the lead and zinc industries, and from these by-products about 100 tons of metallic cadmium is recovered. If all the cadmium dusts and residues were treated the output of metallic cadmium would be small in comparison to the 19,000 or 20,000 tons of tin annually used in this country in solder, even if due allowance is made for the fact that one pound of cadmium can replace from 3 to 5 pounds of tin.

The Inflammability of Aluminum Dust. A. LEIGHTON. (*U. S. Bureau of Mines, Technical Paper 152,* January, 1919.)—As prepared, the aluminum dust of commerce is finely divided aluminum metal with a coating of oil, usually stearine or some similar material. This coating evidently serves to prevent oxidation in air and to protect the metal particles from the action of moisture, as it is stated that the product loses its lustre if no oil be added. Aluminum dust is so light that it is easily blown about a room, and as the workmen seldom take precautions to prevent this the workrooms are soon coated with the dust. Evidently all apparatus should be inclosed to prevent loose powder from being blown into the air. Although experiments do not show the exact conditions under which an ignition of the aluminum dust is obtained, they do show that it may ignite at temperatures even lower than those necessary for the ignition of 200-mesh standard Pittsburgh coal dust; also more heat is needed to ignite aluminum dust. The dust used in the tests was a commercial product labelled "aluminum bronze."

OIL-SHALES.

BY

DEAN E. WINCHESTER.*
Geologist, U. S. Geological Survey.

It has been said, and probably said on good authority, that the great world war was won by petroleum, and we are all more or less familiar with the phenomenal growth of the gigantic industry which has proven itself capable of supplying not only the demands of our own military activities but in part those of our allies and at the same time furnishing the fuel for the countless motors and engines used by the people of the United States in commercial and pleasure pursuits. A glance at the figures showing the relation of the amount of petroleum consumed each year to the amount produced reveals the startling fact that the consumption has been rapidly approaching the production, and since 1915 it was even necessary to actually draw on the reserves in storage in order to meet the increased demands, and this while our oil men were straining every nerve to increase the output of petroleum both by discovering new fields and by developing to the limit the proven areas. The newly discovered fields have given us an increased production, but the total amount of petroleum derived from these fields has been insignificant in comparison to the total needs of the country. Is it any wonder then that men and companies are asking if it is not possible for the oil-shales of the United States to give us relief? After spending nearly five years in studying the oil-shales of the western part of the United States I am thoroughly convinced that the day is not far distant when these very shales that the cattle men and farmers of the Rocky Mountain region have sworn at so often because they make neither good farm land nor good range, will be yielding oil in sufficient amount to prevent the rapid decline in our total oil production, which is imminent if no new source of petroleum is developed. There seems to be every indication that in the near future (perhaps within ten years) there will be established in Colorado and Utah an industry for the mining and distilling of oil-shale which will rival in size any of the mining or manufacturing industries now developed in the United States. At this very time there are at least seventy-five companies organized for the purpose of manufacturing oil from the shale, and many of these companies are contributing considerably towards the research that will ultimately place the industry on a firm foundation.

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* Presented at the Stated Meeting held Wednesday, February 19, 1919, and published by permission of the Director, U. S. Geological Survey.

Bright as the future seems to be for oil-shales it must be remembered that before a profit-paying industry is established large sums of money must be expended in the development of processes and practical machinery for extraction of the valuable products of the shale. The cost of producing shale-oil must include such items as mining, transportation of the raw shale from the mines to the retorting plant, crushing, retorting, condensing, manufacture of ammonium sulphate and disposal of the spent shale, which will weigh at least 60 per cent. as much as the shale as it comes from the mines and will probably be only slightly less bulky.

Unfortunately the word " oil-shale " brings to the mind of the uninitiated visions of wealth similar to the wealth that has come to those oil men who have been fortunate in making strikes in the oil fields. The oil-shale industry is to be more like the great Bingham, Utah, copper district, where thousands of tons of low-grade ore are handled daily and where each ton yields only a small profit. Enormous capital will be required to establish a profitable oil-shale plant, and men with small means should be very careful before investing it in oil-shale to be sure that the company in which they invest has ample capital and good, sound, thorough men at the head who are willing to spend large sums in experimental work before returns are forthcoming.

Several years before the first discovery of petroleum in 1857 *" coal-oil "* was being made from cannel coal and black shale in the eastern part of the United States, and it is reported that at the time of the first discovery of petroleum sixty companies had been organized and many of them equipped with the necessary machinery for making oil from the rocks, but the newly discovered fuel proved so cheap that all these attempts at manufacturing oil were abandoned. Recently the increased demands for petroleum and the high prices paid for gasoline, fuel oil, etc., have revived the idea that it may be both practical and profitable to distil oil from rocks. This time attention is being directed largely toward the rich oil-shales of the Rocky Mountain States.

In order that the subject of oil-shale may be rightly understood it is essential to have a clear idea of the difference between an oil-shale and an oil sand. The petroleum of to-day is coming largely from oil sands, but it may not be amiss to prophesy that it will not be many years before oil-shales will furnish oil in large quantity. An oil sand is a more or less porous rock between the grains of which the oil is entrapped and from which the oil may be extracted by solvents or mechanical means or from which oil will flow when the sand is penetrated with the drill. Oil-shale, on the other hand, is a very fine-grained and compact rock which contains practically no free oil but which does contain an abundance of partly decayed and bituminized organic matter from which oil can be manufactured by simple distillation processes.

Practically all oil-shale is tough and hard to break, and some of the thin-bedded varieties are remarkably flexible. All oil-shale is thin-bedded, although some of the beds weather into massive ledges, in which case the thin-bedded character is evident only after the shale has been heated and the oil driven off. On the exposed surfaces oil-shale weathers to a bluish-white color, but the weathered surface is only skin deep, so to speak, for usually within less than an inch from the outside the shale is unaffected and has the characteristic dark-brown or black color; the darker the color the richer the shale. When freshly broken, oil-shale gives off an unmistakable odor of petroleum, but this quickly vanishes, so that within a few minutes after the rock is broken the asphalty odor has entirely disappeared. Many of the richest shales of the Green River formation of Colorado, Utah, and Wyoming have a peculiar waxy or velvety lustre and resemble in a way cannel coal. Still other and equally rich shales are dark brown, and in the case of the rich oil-shale from near Elko, Nev., the rock is yellowish-brown and lustreless. Most of the oil-shale beds are composed of alternating dark and light colored laminæ with the relative richness of the bed depending on the preponderance of the darker colored material. Good oil-shale will burn with a sooty yellow flame when it is ignited with a match. In the region where the oil-shales outcrop, campers and cow men very often use the shale for fuel in their campfires, and in some places I have even seen the rock used in the stoves. This latter use, however, is not very satisfactory on account of the great amount of ash which oil-shale contains. Late in the fall of 1918 my little party was working near the great cliffs of oil-shale in northwestern

Colorado when much to our dissatisfaction the weatherman decided to give us a week of rain, and as a result everything, even the firewood, was wet and there was no coal within twenty-five miles. A happy thought, and after a little coaxing a fire was kindled and blocks of oil-shale which lay all around on the ground were piled over it. Very soon we had a rousing fire, even if it was sooty, and those rocks burned furiously for at least three hours and in the end the camp washing was done.

Valleys near the outcrop of the oil-shale are always strewn with the boulders of shale which have been broken from the ledges at the outcrop, and in many places these large angular pieces have been carried miles from their original resting place without disintegrating in the least, for weather has very little effect upon the oil-shale. The story is often told in the shale regions how a certain rancher built a new cabin and made the fireplace and chimney out of the blocks of shale which he found strewn about over his fields. The very first time that he made a fire in the fireplace his house was destroyed, and not even the chimney was left standing, for that, too, burned, and there remained only a bed of soft ashes after the flames had been quenched.

Oil-shale is much lighter in weight than coal, and the lighter it is the more oil can be distilled from it. Coal with an ash content of 10 per cent. is considered pretty poor fuel, but the oil-shale which I just described burns furiously when once started and yet has 50 to 70 per cent. ash and therefore could not be used as fuel satisfactorily.

The Green River formation contains the richest and most extensive beds of oil-shale known, but not the whole formation is oil-yielding. Rich oil-shale is interbedded with lean or barren shale or in a few places with oölite and sandstone, and because of its resistance to the weathering agencies beds of rich oil-shale ordinarily project beyond the rest of the rocks which are present in the cliffs. Along the south side of the great Uinta Basin in Colorado and Utah for a distance of 150 miles or more there are beds of oil-shale thick enough to mine and rich enough to warrant the establishment of an industry of immense proportions; in fact, nearly 4,000,000 acres in this region have been classified by the Government as land valuable for its oil-shale. The greatest thickness of rich oil-shale beds is in the eastern third of this great area, and in the part of the field near De Beque and Grand Valley, Colo., and Watson, Utah, there are beds of rich shale aggregating more than a hundred feet, and much of this shale is capable of yielding more than a barrel of oil to the ton of shale.

Oil-shale beds in most places lie nearly horizontal, much as the coal beds in the western part of Pennsylvania, but different from the coal in that oil-shale beds outcrop high up on the sides of great mesas 2000 to 3000 feet above the valleys. Because of this, when our engineers begin to work the shales they will have to install long and expensive tramways to bring the shale down to the elevation of the distillation works, which will necessarily be located in the valleys near water and transportation.

The shales of the Green River formation were all laid down in fresh water lakes in which grew great masses of vegetation and into which the pollen and leaves of the higher plants were washed and blown by the winds. Large numbers of insects swarmed the air in those days and their bodies were buried in the slimes and mud at the bottom of the lakes, and these shale beds now contain an abundance of excellently preserved fossils. During the last two field seasons considerable time has been spent studying these records of the life that thrived when our oil-shales were being made. The fossil collections now include beautifully preserved beetles, flies, mosquitoes, bees, leaves of all kinds, fish skeletons, and even bird bones. And in addition to these fossils which are visible to the naked eye the microscope brings to light an immense variety of tiny organisms, many of which are easily identified but others of which are as yet not understood. The richer oil-shales contain an abundance of vegetable material, including such types as ferns, fungi, bacteria, algæ, and pollen, perhaps the most remarkable of these being the algæ. It is difficult to imagine under what conditions such delicate forms as the water trough slimes could be imbedded in mud and then the mud become hardened to the tough shale as we find it to-day and still have the cellular form of these soft plants preserved. This is one of the wonders of oil-shale. The immense amount of organic material in the rich oil-shale and the relative absence of such material in the leaner shales may be a mere coincidence, but when it is realized that it is practically impossible to extract any oil from even the richest shale by any means except heat, then it seems that the oil must be made by the destructive distillation of the organic material and that in all probability the larger part of the oil comes from the vegetable matter in the shale, and perhaps most of it from the lower forms of vegetation such as the algæ.

The richest oil-shales in the United States belong to the Green River formation of Eocene age and are to be found in Colorado, Utah, and Wyoming, but these are by no means the only shales which will yield oil when distilled. The Devonian black shales, for instance, which underlie great areas in the eastern part of this nation, are in most places oil-yielding, but the amount of oil that they will yield may be too small to allow their commercial development. Only a very rough reconnaissance study of these shales has been made, and it is not at all certain that more careful search in Indiana, Ohio, New York, Pennsylvania, Kentucky and Tennessee will not disclose areas where the shales of this age are sufficiently rich to warrant their being worked. In general the oil-shales of these older geologic formations have the same characteristics as the oil-shales of the Green River formation.

Cannel coals are as a rule capable of producing a goodly quantity of oil when subjected to distillation, and where the cannel coal is so high in ash as to prevent its use as a grate fuel it is well worth while to consider the mining and distilling of such material for its oil and ammonia values. The bony coal which is found in connection with some of the bituminous coals may also be worthy of consideration, although this kind of material will probably yield very heavy oil or tar when distilled.

In western Montana certain dark shales belonging to the older formations (Upper Paleozoic age) have been found to yield a moderate amount of oil when distilled, and in addition some of these shales contain phosphate, an element which is much in demand for its fertilizing value. If the phosphate in these shales is in some form that can easily be made usable it is quite possible that these shales can be treated jointly for their phosphate and oil values at a profit, but it is certain that the cost of operating them for their oil alone will be prohibitive.

A broad field is open to those interested to determine what substances there are in the United States which are capable of yielding liquid oil products when distilled. The Germans have for many years been distilling lignites, and perhaps our own lignite of North Dakota and Montana, as well as Texas and the Gulf Coast States, will find a market through this channel. It is certain that many of the " fatty " lignites are worthy of investigation with this in view. Experiments are already being carried on to determine the possibilities of the North Dakota lignites as oil producers.

Organic deposits like oil-shale and coal contain a considerable percentage of nitrogen, and the successful development of oil-shale may depend largely upon the economical recovery not only of the oil but the nitrogen of the shale. Recent analysis of nearly two hundred samples of oil-shale has uncovered the fact that American oil-shale is different from the Scottish oil-shale in that in the oil-shale of the Green River formation the percentage of nitrogen increases with the richness of the shale. It is reported that in the shale being mined in Scotland the shales richest in oil are poorest in nitrogen. Although the percentage of nitrogen in the oil-shales of the Green River formation of Colorado is not as great as the percentage in ordinary coal, the recovery of this valuable element will add only a small cost to the process of treatment in proportion to its value.

We in America have never been driven to the development of our natural resources to the extent of many of the other nations of the globe. In Japan, for instance, the people are forced to artificially terrace the rocky mountain sides in order to make room to grow sufficient farm and garden products to maintain the population of the islands. In Scotland no petroleum has been found, and the people long ago perfected processes for extracting oil from the oil shales of their territory, and for more than sixty years there has been an industry in Scotland which has supplied much of the oil needed for its industries. In each of these places the people have risen to the occasion and have devised means to provide the necessities from the materials at hand. Records show that in Scotland the shale treated averages only about twenty-four gallons (little more than half a barrel) of oil per ton of shale. What the Scot can do with this medium grade oil-shale we surely can do with a shale which will yield perhaps twice as much oil if not more.

Within the past five years numerous individuals and companies have devoted a great deal of attention to the oil-shales of the western part of the United States. Much of the more favorably located land has been filed on as mineral land under the mining laws of the nation and in a few cases the Government has actually been asked to transfer the patent to this land to private individuals. Several of the companies are carrying on extensive chemical and engineering research looking toward the development of efficient and practical processes and machinery for getting the oil and other valuable products from the shale, and at the present time there are at least a score of different processes proposed and partly perfected for the distillation of oil-shale. Many of these are doubtless destined for discard not because they fail to produce the shale-oil, but because they either will not produce the right kind of shale-oil or the oil produced will cost more than it can be sold for.

The United States Bureau of Mines is conducting experiments and investigations looking toward the utilization of the oil-yielding shales of the western States, but it will necessarily be some time before the results of this work can be published.

During my own field studies of the oil-shale for the U. S. Geological Survey in the last five years I have found it of great value to the work to make distillation tests of samples of oil-shale in the field, and for this purpose I have carried with me a small apparatus in which I could heat a weighed amount of crushed shale and condense the vapors which were formed and measure the resulting distillate. This apparatus consisted simply in a small (half-pint) iron retort connected to a simple all metal water-cooled condenser. Heat was furnished by a small gasoline plumber's torch, and the distillates were measured in a glass graduate. Crude as was this field apparatus I have found that it was possible to vary to a remarkable degree the kind of oil that would be derived simply by changing the quantity of heat used, and no doubt if it had been possible to vary other conditions pertaining to the distillation, such as pressure, etc., additional variations in the product would have resulted. For instance, if I rapidly increased the temperature of the shale till it was heated to red heat I got a very different character and quantity of oil than that received when early in the treatment I raised the temperature very slowly. If a slight manipulation of the conditions of heating in this crude apparatus will make such a difference in the character of the product, then it seems that until we have shale-oil produced in a commercial plant there is little value in having a chemist determine carefully the characteristics of shale-oil. This is the more important when it is realized that no two of the many processes that are being proposed for oil-shale distillation are designed to subject the shale to the same conditions. As soon as there is in this country a commercial plant for the production of shale-oil we can find out what shale-oil is and how it compares with the petroleum of the various oil fields. Roughly, I believe that it is safe to prophesy that the shale-oil of the future will yield on refinement products that are quite similar to those that are manufactured from ordinary petroleum, but until we know what the shale-oil is and what it will produce it is obvious that no one can state in more than general terms what will be its value in dollars and cents. I will not be at all surprised to see products not now produced from oil-well petroleum developed commercially from shale-oil.

The shale-oil that has been produced in the Scottish oil-shale industry is a thick green oil which at ordinary temperatures has much of the consistency of vaseline, and if the oil that is to be produced from our own oil-shales is similar to that made in Scotland we must devise other means than pipe lines for transporting it from place to place. Fractional distillation of the shale-oil that was produced in the small testing apparatus used in my own field examinations gave about 12 per cent. gasoline and 35 per cent. kerosene, with as much as 9 per cent. paraffin. These figures are not at all complete or final but they serve to give us a general idea of the character of shale-oil.

In the distillation of oil-shales there are four primary products, namely, oil, gas, water and spent shale. The character of the oil will vary somewhat with the character of the original shale, as, for example, the shale-oil from the shale near Elko, Nev., is much higher in paraffin than most of the shale-oil that has been produced by the same methods from shale of the Uinta Basin in Colorado and Utah, but the greatest differences that will be found in the shale-oils are likely to be due to the conditions under which the shale is distilled.

Gas will be made in the retorts which will not be condensed to oil. This will contain ammonia, which can easily be extracted and converted into commercial ammonium sulphate, which is valuable as a fertilizer. The average nitrogen content of shales of the Green River formation yielding more than 15 gallons of oil per ton is theoretically equivalent to about 50 pounds of ammonium sulphate per ton shale, and, of this, commercial practice should recover at least 60 per cent., so we may expect that our shales will yield at least 30 pounds of ammonium sulphate from each ton of shale distilled.

Nearly all rocks contain water, and oil-shale is no exception, and in their distillation for oil the water will, of course, be vaporized and condensed along with the oil. It has been found in the Scottish practice that the recovery of nitrogen from the shale is assisted by the addition of water or steam to the shale while it is being heated, and if this is found advantageous with the American shales the amount of water which is discharged from the condensers will, of course, be large. This water should contain most or all of the ammonia which is formed in the retort by the decomposition of the nitrogenous compounds in the shale.

One of the great problems connected with the recovery of the valuable products from oil-shale will be that connected with the ash or spent shale. In the small testing apparatus some of the richer shales have been found to fuse and slag together and their removal from the retort thus made difficult. In the larger retorts it may be found that the injection of steam into the heated shale within the retort will help prevent this caking as well as help to secure the maximum recovery of the nitrogen of the shale, or it may be found necessary to agitate the shale while it is being treated, or even mix the rich shale with leaner material. These are some of the problems to which the chemist and engineer must give attention. Furthermore, it is to be expected that the satisfactory operation of a given apparatus using one type of shale will not constitute proof that the same machine will produce equally good results from all oil-shale. For instance, the methods and apparatus found efficient for the mining and treatment of the oil-shale from near Elko, Nev., will doubtless have to be greatly modified before they will produce good results when used in connection with the shales of northwestern Colorado.

So far as at present known there seems to be little proof that valuable substances remain in the spent shale, and since a plant which is built to handle 1000 tons of raw shale per day must handle and dispose of probably 600 tons of waste material whose bulk is only slightly less than the original shale, the problem of the disposal of this spent shale is one which must be solved before the plant is established, as ample dumping ground must be available. It has been suggested that this waste might contain potash or phosphate, but none of the samples so far analyzed by the Geological Survey have been found to contain sufficient soluble potash to warrant a quantitative determination, and only the black shales of the Phosphoria formation of western Montana have been found to have a high percentage of phosphate in combination with oil-yielding ability.

Reports that oil-shale was rich in gold, silver, lead, zinc, platinum, etc., have been circulated and have attracted much attention, but to anyone who is familiar with the conditions under which such metals accumulate the chances seem very small for finding commercial quantities of shale which will yield values in these elements. I have been informed that in a large number of samples assayed by the University of Colorado some of these metals have been found, but in no sample was the combined value for the metals found to be much more than $1 per ton.

Chemists experimenting with the oil-shale and the shale-oil produced from them are making many and varied products—rubber substitutes for use in automobile tires, gaskets, and other places; beautiful dyes and powerful explosives; paints and many other interesting things, but the great question is not what is it possible to make but what can be manufactured profitably. Again we must wait for answer till shale-oil is being produced commercially.

Like all new enterprises there are any number of ideas as to the correct way to treat oil-shale to get the best results. I have had the privilege of seeing the designs of many of these processes and of seeing the machinery installed for a few of them, and I will give a brief outline of the principles of those which I have seen, more to illustrate the widely divergent ideas than to give details of the processes.

One of the first plants erected and tried out on the western oil-shale consisted of a metal tube about 30 feet long and a foot in diameter set in a brick fireplace and inclined at an angle of about 10° to the horizontal. Partially crushed shale was fed into the tube at the lower end and carried slowly upward through the retort by a screw conveyor and discharged at the upper end. Heat was applied to the retort about midway between the ends, so that in traveling the length of the tube the shale was gradually heated to red heat and then gradually cooled till it could be easily handled at the discharging end. The volatile products are removed by slight suction at the intake end of the retort.

A second process consists in a metal chamber or retort, cylindrical in form and standing on end. Raw shale is fed into the top and passes downward and at the same time the temperature is increased. The lighter hydrocarbons are supposed to be distilled off from the shale in the upper part of the retort and the heavier hydrocarbons used for fuel in the lower end of the same retort where the half-spent shale is burned.

One retort which is being installed by several companies with properties near De Beque, Colo., consists of an inclined trough with cover, set in a brick oven. The cover is equipped with numerous exit tubes through which the volatilized products of the distillation are allowed to escape to the condensers. Finely crushed shale is fed into the upper end of this retort and conveyed down by a mechanical agitator. The maximum heat is applied to the lower end of the retort, so that the temperature to which the shale is subjected increases as the shale travels down the 30-foot long retort. The numerous exit tubes are supposed to allow partial fractionation of the oil as it is formed.

Still another distilling apparatus which has been tried out consists of three iron tubes placed horizontally one above the other and communicating at alternate ends. Shale is fed into the upper tube and conveyed through the three consecutively by screw conveyors. Each tube is provided with exit for the gases evolved in it and these are condensed separately, so that at least theoretically there is a three-part fractionation of the crude shale-oil as it comes from the retort. Heat is applied to the lower tube and conducted beneath the other tubes, so that the least amount is applied at the point nearest where the shale enters the system.

The retorts now used in Scotland are the growth of many years of experimentation. The earliest apparatus used there consisted in horizontal tubes, but these were soon discarded in favor of the vertical tubes, and at present the principal retorts consist of tall cylinders somewhat larger at the bottom than at the top and provided with no force but gravity to convey the shale from the top down to the point of exit after it is freed of its oil-forming substance. Some of the older vertical retorts were provided with internal agitators, but these were sooner or later discarded because the operation of metal parts in the highly heated chamber gave endless trouble. Heat is applied externally to the retorts, and the fixed gases from the shale provide ample fuel for the heating of the retorts. Gases are conveyed from the retorts into large air-cooled condensers consisting of many vertical tubes or pipes. After this such gas as is not condensed is scrubbed for ammonia by washing with water and for additional naphtha by washing with heavy oil. In the Scottish industry it has been found that the permanent gases are more than sufficient to heat the retorts.

Two processes are being perfected in America each of which uses modifications of the Scottish retorts, and each of these will use condensers of special design and radically different from the simple air-cooled condenser used in Scotland.

At least one retorting system proposed for our American shales embodies the principle of removing the gas from the centre of the shale chamber on the theory that this will prevent to a maximum degree the cracking of the oil into undesirable gases. In this machine heat is applied externally to the large cylinder containing the shale. In the middle of this cylinder there is a perforated exit pipe through which the gases are drawn off and sent to the condensers.

One of the most complicated retorts designed for the distillation of oil-shale comprises eight communicating chambers, four of which are provided with a hearth attached to a revolving shaft and four of which are furnace chambers into which the heat is applied. These heat and hearth chambers alternate one above the other; the shale entering the topmost chamber first is carried by a rotating agitation system across the first hearth and then consecutively to the second, third and fourth, the temperature being higher in each chamber. The vapors are removed from each chamber separately and condensed, so that the oil is partially fractionated as it comes from the retort.

Oil-shale, as has been said, is a rock from which the oil and other products may be distilled, but before the shale is ready to retort it must be mined like coal and crushed. Within the areas in the Rocky Mountain States that are underlain with rich oil-shale there are many small tracts where the shale is sufficiently close to the surface to be mined with a steam shovel, but most of these tracts are remote from transportation and therefore may not be used in the first stages of the developments. We must therefore now look carefully to the conditions that will affect the methods and expense of underground mining. The shale lies in "blanket form" like coal, and in most places the beds are practically horizontal, so that none of the difficulties incident to the mining of steeply tilted beds such as are met in the oil-shale industry of Scotland will be encountered. The rich oil-shale beds are usually overlain by beds which will not be affected by weather, so that little trouble is to be expected with roof. The shale may be harder to mine on account of its toughness, but machinery will be developed which will cut and drill the rock without difficulty. The cost of mining shale will be at least as great as the cost of mining coal in the same region.

After the shale is mined it must be transported to the retorts, and because of the fact that the shale beds outcrop high on the sides of mesas, in some places 2500 feet above the sites which must be chosen for the retorting plants, this transportation will necessitate the installation of tramways in some cases a mile in length. Then the rock must be crushed to the appropriate size before it is ready to go to the retorts. The fineness to which the shale will be crushed depends upon the process that is adopted for its treatment. One of the methods proposed requires that the shale be crushed to a powder; others propose to handle shale almost as it comes from the mine. For the task of crushing the shale it may be necessary to design and construct crushers of special model, as there will be a tendency for the shale to gum and pack in the crusher.

At the present time there is no exact or satisfactory information regarding the cost of any of the phases of this new industry. The installation of a tramway system capable of delivering shale to a commercial sized plant will probably mean the expenditure of \$15,000 or \$20,000, and the crushers will cost money to install as well as operate. The cost of a retorting system has been estimated at from \$300 to \$2500 per ton of shale to be treated per day, depending on the system that is to be used. The cost of operating the apparatus after it is installed is, of course, as uncertain as the original cost of the plant because of the undeveloped stage of the machinery. The following figures showing the pre-war costs of the Scottish industry can for want of better be considered as the best figures available. The installation of a large Henderson retorting plant before 1909 was quoted as about \$350 per ton daily capacity, and the cost of operation, including mining, crushing, with the production of crude shale-oil and ammonium sulphate, was \$1.86 for each ton of shale handled. After this it remains for the shale-oil to be refined before the maximum value is obtainable.

In conclusion, therefore, it is evident that we have material in abundance which is capable of furnishing the oil that we need for the future operation of our motors, but before this raw material can be used it must be dug from the earth, then it must be treated in elaborate and expensive apparatus which is as yet unperfected. The successful oil-shale plant will necessarily be one capable of treating at least 1000 tons of shale per day, for it will be possible under efficient and economical management to realize only a small profit from each ton of rock handled. Before the oil-shale industry is on a profit-paying basis much time and money are bound to be spent, and a great many people who have been led to believe that the oil-shale industry will rival the gusher oil well as a money maker will be disappointed. However, I can see no other way but that eventually the oil-shale of Colorado, Utah, Wyoming, and perhaps some of the other States, will be made to produce oil, fertilizer, and profits in large quantity.

Machine Tools. A. HERBERT. (*Proceedings of the North-East Coast Institution of Engineers and Shipbuilders*, March 11, 1919.)—Probably in the potter's wheel is to be found the first germ of the machine tool itself. From producing by the aid of a rotating spindle cylindrical forms in plastic material, it is no great step to the invention of the first crude woodworking lathe, but the modern machine tool is a product of comparatively recent times, and its development coincides very closely with that of the steam engine. To Maudslay on the one hand, and to Whitworth on the other, we, as users of machine tools, owe the greatest debt. Maudslay is credited with the production of the first slide rest, and it was Whitworth who, by his accurate plane surfaces, and by his wonderful progress in exact measurements, became the father of mechanical accuracy. Given the ability to produce reasonably accurate cylindrical and plane surfaces, and given the slide rest, the evolution of machine tools became simply a question of time.

The lathe undoubtedly was the first real machine tool. It is of all machine tools even to-day the most important and the most universal, and in fact, a lathe with appropriate attachments is capable of performing, after a fashion, most of the machine shop operations. The shaping machine, or " iron arm " as it was originally called, was also very early in the field, and from these two primitive types all the modern highly specialized machine tools have gradually been evolved. In direct line of descent from the lathe, we find the milling machine, the boring machine, the drilling machine, the screwing machine, the capstan lathe, the automatic screw machine, the automatic turning machine, the universal and plain grinding machine and the boring and turning mill. From the shaping machine are descended the slotting machine, the planing machine and the surface grinding machine. Each of these various machine tools has been taken in hand by innumerable designers and developed into specialized types to meet the constant growth of demand—until to-day the machine tool family is enormous, both in range and in variety.

It is well that we should acknowledge our indebtedness to the United States for much of our progress in machine tool production and in workshop methods. American tool builders were stimulated to a great extent by the high level of wages. In this country wages for many years were at a comparatively low level, and British employers therefore did not have brought home to them the necessity of employing labor-saving machinery in anything like so forcible a manner as was the case in America. Repetition work was first seriously developed in the manufacture of small arms and of sewing machines. As soon as the possibilities of repetition work were realized, an immediate impulse was given to the improvement of machine tools and of measuring appliances and jigs and fixtures. In England the early importation of American machine tools soon demonstrated that there was a market there for machinery of this class, and their gradual introduction among the more refined industries, had a valuable educative effect both on machine tool users and on the English machine tool trade.

The discovery of high-speed tool steel marked an epoch in machine tool design. It was indeed startling to find one's whole basis of thought completely upset. For years the limiting factor in the metal moving capacity of machine tools had been the endurance of the carbon steel cutting tool, which failed by softening and losing its cutting edge whenever heated by the friction of the cut sufficiently to draw its temper. The new self-hardening steels at once changed the limiting factor to the machine tool itself, for it became evident very soon that existing machine tools did not possess either the power or rigidity necessary to get from the new steels the results that they were capable of giving.

The immediate result was the scrapping of machine tool patterns throughout the country, and the production of new designs embodying much greater weight and stiffness, accompanied with enormously increased power. A further development was a radical change in headstock design. It was soon evident that existing designs of lathe headstock failed to give the power required at the high speeds necessary to utilize the cutting capabilities of high-speed steel. Ideas of power, convenience, safety and quick-changing facilities spread very rapidly through the whole range of machine tool design, and were applied not only to main drives but to the feed motions. Comparatively recently the attention of designers has been directed towards relieving the operator of a good deal of the laborious work involved in moving saddles and other elements of machine tools; and in modern machines power operated adjustments are becoming standard practice on all the heavier types.

HOW THE NITROGEN PROBLEM HAS BEEN SOLVED.* †

BY

HENRY JERMAIN MAUDE CREIGHTON,
Department of Chemistry, Swarthmore College.
Member of the Institute.

VI. THE OXIDATION OF AMMONIA.

Since, with the exception of the arc process, all methods for the fixation of atmospheric nitrogen yield products which are readily converted into ammonia, its oxidation to nitric acid is one of the most important phases of the nitrogen problem. Although it was discovered in 1830 by Kühlmann that ammonia could be oxidized in the presence of platinum, it was not until the process was developed by Ostwald in 1902 that it became of technical importance. During the past few years various methods have been developed which effect the direct oxidation of ammonia by air in the presence of a catalyst.

OUTLINE OF THE PRINCIPLES UNDERLYING THE OXIDATION OF AMMONIA.

When a mixture of ammonia and air is allowed to flow through a heated catalyst (sometimes called the " burner "), nitric oxide is formed, in accordance with the equation:

$$(27) \quad 4NH_3 + 5O_2 = 4NO + 6H_2O + 220{,}000 \text{ cal.}$$

The oxide produced by this reaction can then be converted into nitric acid in a manner similar to that previously described under arc processes.

At low temperatures little or no nitric oxide is formed, but as the temperature is raised the rate of oxidation increases very rapidly, reaches a maximum at about 750° C., and then rapidly decreases, owing to the decomposition of the ammonia into its constituents. This change is shown graphically by the heavy curve (" conversion curve ") in Fig. 17, for otherwise constant conditions, such as the composition of the gas mixture, rate of flow through the catalyst, etc.

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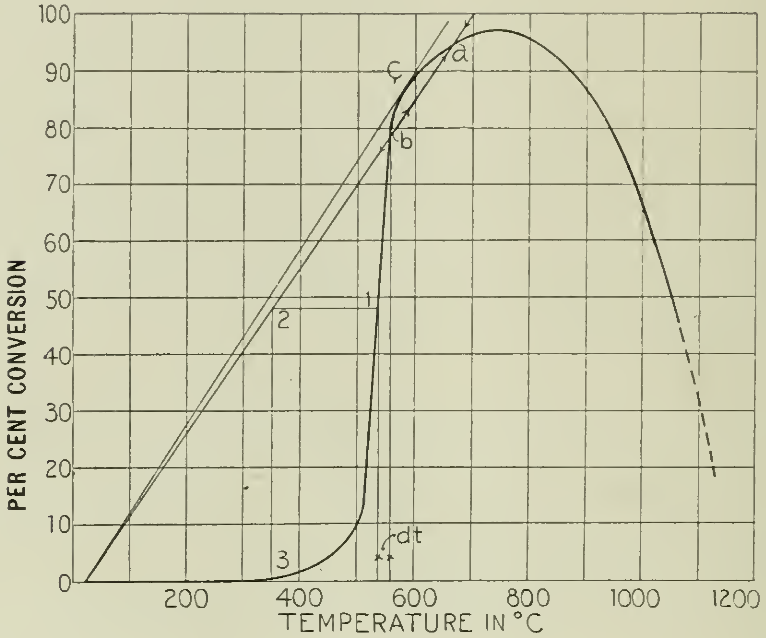
* Communicated by Professor Creighton.

† Concluded from page 610, Vol. 187, May, 1919.

The reaction is highly exothermic, the heat of reaction being practically constant and equal to 53,000 gram calories between 500° C. and 700° C. It has been calculated that, under the usual conditions of oxidation and on the assumption of 100 per cent. conversion, the heat of reaction is sufficient to raise the temperature of the moving gas mixture to 675° C. at the catalyst. If, therefore, the initial temperature of the ammonia-air mixture is 25° C., the temperature of the catalyst will be raised to 700° C. The smaller the percentage of ammonia converted into nitric oxide, the smaller will be the rise in temperature due to the heat developed during the reaction, and the lower will be the temperature of the catalyst. The variation in the temperature of the catalyst with change in the percentage of ammonia converted is shown by the straight line ("heat-of-reaction line") in Fig. 17.

FIG. 17.



In a theoretical discussion of the conditions of stability of ammonia oxidation, Liljenroth,[6] in a recent paper, states: Since "the heat-of-reaction line cuts the conversion curve ordinarily at two points, *a* and *b* (Fig. 17), it seems, therefore, as if it would be possible to have two points of operation for any burner (heated catalyst) at a given gas composition and gas flow. But a closer investigation shows that the reaction cannot be maintained at the point *b* because the conditions for stability at this point are not fulfilled. Suppose that the burner is working at this point and that for some reason the temperature decreases by the small amount *dt*. Then the conversion will decrease to the point 1. This decrease will cause the temperature to be lowered still more, to point *2*, and this in turn will cause a new decrease in the conversion, to point *3*, and so on.

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[6] Liljenroth, F. G., *Chem. Met. Eng.*, **19**, 287 (1918).

"If we assume that for some reason the temperature increases, it will in the same way be found that even in this case we move away from the point of intersection, which is indicated in the illustration by the arrows pointing apart from this point.

"If we treat the other point of intersection similarly (point *a*), it will be found that the conditions are just opposite. If for some reason we depart from the point, we will immediately be carried back to it, which is indicated by the two arrows, both pointing toward the point. Point *b* is therefore an unstable location, while point *a* is a stable one. As can easily be understood, this characteristic difference depends upon the manner in which the heat-of-reaction line cuts the conversion curve. In order to obtain stability, the heat-of-reaction line must cut the conversion curve from below, and from this it follows that the part of the conversion curve to the left of the tangenital point *c* is unstable, but that the part to the right is stable. It will also be understood that the stability or unstability increases with increase in the size of the angle at which the line and the curve cut each other.

"From what has been said regarding the unstability of the point *b*, we can now understand that the ammonia oxidation process is not self-starting or self-exciting, but that the gas, in order that the reaction may be started, must be heated by a flame or electricity" to the ignition temperature *T*, which lies considerably below the reaction temperature, after which the external heating may be interrupted and the reaction will move to the point *a*.

In practice the conversion curve and the heat-of-reaction line continually change their positions, on account of small variations in the composition and velocity of the gas mixture. A decrease in the ammonia content of the gas mixture causes the heat-of-reaction line to turn counter-clockwise about its point on the abscissa. "Ample margin between the points *a* and *c* must therefore be provided. If the top of the conversion curve is sharp, it will be impossible to work at a maximum efficiency, because we have to move the working point farther to the right side, sacrificing efficiency in order to obtain stability. This also implies higher temperature. If the conversion curve is very flat, which seems to be the case in the ammonia oxidation reaction, it will be possible to work not only at the top point, but even a little to the left of it."

Of the various catalysts that have been employed for the oxidation of ammonia, the most satisfactory is platinum gauze of fine mesh, or smooth platinum the surface of which has been roughened by the deposition of a layer of platinum sponge. Platinum black or sponge alone is much too active. The best results are obtained with a thin layer of the catalyst, as a thick layer, or a low gas velocity, causes the nitric oxide that is formed to break down into its constituents. Other catalysts which have given good results are palladium, iridium, rhodium, iron, and the oxides manganese, lead, silver, copper, chromium, nickel, cobalt, vanadium and molybdenum, especially the higher oxides.

Particularly good results have been obtained in England with iron catalysts which have been activated with certain metals (" promoters ") such as copper, bismuth, cerium, tungsten, etc. The percentage conversion obtained at 700° C. with a number of these activated iron catalysts is given in Table X, the time of contact of the gas mixture with the catalyst being 0.015 second.

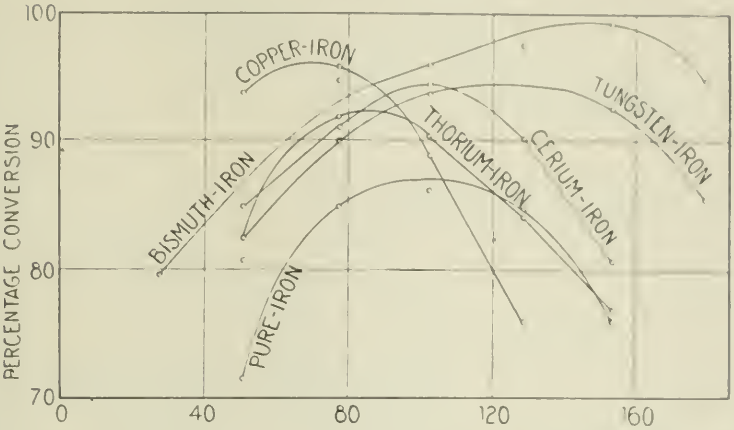
TABLE X.

Catalyst.	Percentage conversion.
Pure iron..............	83.5
Iron-copper............	86.0
Iron-thorium...........	87.3
Iron-tungsten..........	89.3
Iron-cerium............	90 0
Iron-bismuth...........	92.0

The relative efficiency of these catalysts at different rates of flow of the gas mixture, and at 700° C., is shown graphically in Fig. 18.

Like all catalytic processes, the oxidation of ammonia suffers from the disadvantage that the catalyst is liable to be poisoned. It is necessary, therefore, to remove from the ammonia by suitable methods of purification all substances which poison the catalyst. While it has been believed that the presence of acetylene in the ammonia-air mixture had a marked deleterious effect on the platinum in the oxidation of ammona, recent experiments have shown this to be due to the presence of phosphine and not to acetylene. The presence of 2 to 3 parts per hundred million of phosphine in the ammonia-air mixture lowers the yield of nitric oxide several per cent., while ten times this amount is ruinous. It is probable that the action of phosphine is cumulative, since the platinum appears to become less efficient with use.

FIG. 18.



Velocity of passage of gas mixture in liters per hour (at room temperature) per c.c. of free space in catalyst chamber. Each c.c. free space = 20 cm.^{2} of catalyst surface.

THE TECHNICAL OXIDATION OF AMMONIA TO NITRIC OXIDE.

Although considerable progress has been made during the past few years in the technical oxidation of ammonia, but little detailed information is available regarding the various processes that have been developed. These processes conform to the following three types:

1. Oxidation by means of a platinum plug (Ostwald process);
2. Oxidation by means of an electrically heated platinum gauze;
3. Oxidation by means of base metal catalysts.

The principle of the first type of processes is that originally patented by Ostwald, but the catalyzer has been considerably modified, although it consists of metallic platinum. Little information regarding the details of the preparation of the catalyzer is available, but it is known to have a very small cross-section. It is placed at the end of a 60-mm. tube. The ammonia-air mixture is preheated before reaching the catalyzer, by utilizing the heat produced by the oxidation. No external heat is necessary. It is stated that the reaction when once started continues without interruption for weeks. The yield is good, averaging 90 per cent., but the temperature regulation is more difficult than in the second type of processes, in which electrical heating is used.

The second type of processes possesses many advantages over processes of the Ostwald type, and is rapidly increasing in favor. A diagram[7] of a catalyzer used in a process (Frank and Caro's) of this second type is shown in Fig. 19. The catalyst is 80–100 mesh platinum gauze electrically heated to 700° C. At the bottom of the catalyzer the air enters on one side and the ammonia on the other. Before these gases mix, they pass through gauge collars, as indicated. The diameters of these collars are selected so that the best mixture for oxidation will be obtained. For further adjustment a valve is placed in each pipe-line. The gases are mixed by a revolving aluminium fan, after which they pass through the heated platinum gauze (no heat exchange taking

Fig. 19.

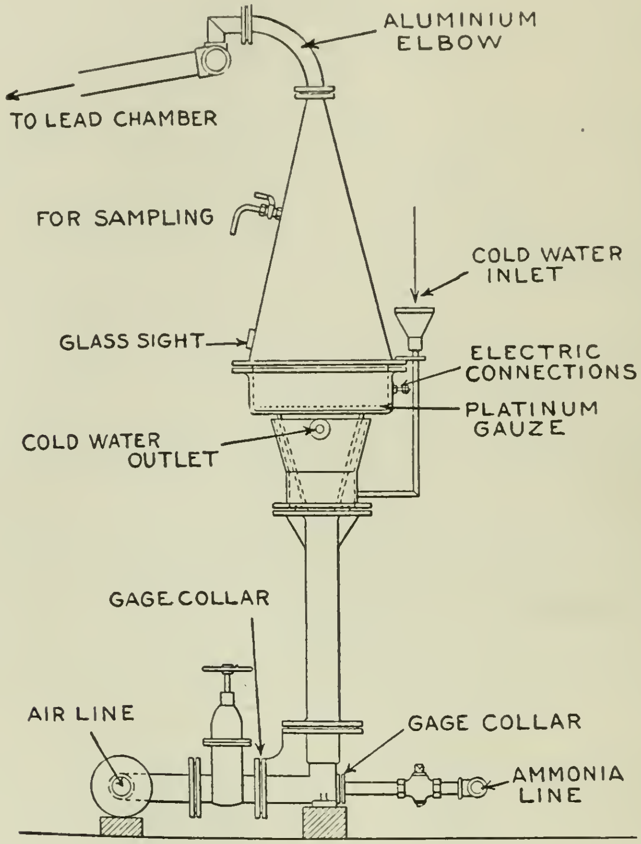


Diagram of Frank and Caro's catalyzer for ammonia oxidation.

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[7] *Chem. Met. Eng.*, 14, 425, 1916.

place), where an almost quantitative conversion of the ammonia to nitric oxide occurs. The lower half of the casing surrounding the glowing platinum gauze is cooled by cold water, in order to prevent as far as possible any decomposition of the ammonia by radiated heat before it reaches the catalyst. The casing above the combustion chamber is lined with aluminium so as to prevent any iron oxide from falling on the catalyst.

The weight of platinum required for this catalyzer is about 47–50 grams per 100 kilograms of nitric acid per 24 hours. The loss due to wear and tear amounts to about 3 per cent. per month, and the gauzes have to be completely renewed once a month. It is probable that the unit described does not contain more than 50 grams of platinum.

To keep the gauze heated, 135 amperes supplied at 25 volts, *viz.*, 3.375 kilowatts, are required. If, therefore, the catalyzer produces 100 kilograms of nitric acid per day, the electrical energy consumed amounts to 0.81 kilowatt hours per kilogram of nitric acid.

A catalyzer in use in England has recently been described by Partington.[8] One form of this is shown in Fig. 20. This catalyzer consists of two aluminium cones, connected by three rectangular aluminium body pieces having a cross-section of 4 in. by 6 in. In the three lower junctions perforated baffle plates are inserted, while the junction between the top segment of the body and the upper cone is occupied by the catalyst frame. The ammonia-air mixture enters at the bottom and the nitrous gases leave at the top, through aluminium tubes having an internal diameter of 2 in. The upper cone is provided with a mica window for the inspection of the catalyst. This consists of one or more platinum gauzes which are stretched across the catalyzer at right angles to the gas flow. The gauzes, having 80 meshes to the inch, are made of pure platinum wire 0.0025 in. in diameter and weigh about 50 grams per square foot. The life of the gauze is about three months. New gauzes require to be used for a few hours before attaining their full catalytic activity.

The ignition temperature is attained by heating the catalyst, either electrically or by means of a non-luminous gas flame, but once the reaction commences, the heat developed is sufficient to maintain the gauze at red heat, and conversion proceeds without interruption.

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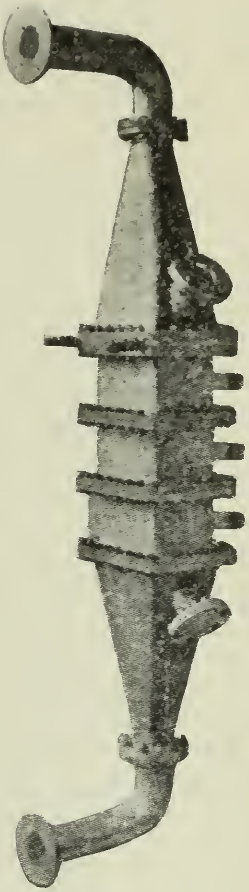
[8] Partington, J. R., *J. Soc. Chem. Ind.*, 37, 337R (1918).

When working under established conditions with this catalyzer, a yield of one and one-half tons of nitric acid per square foot of catalyst area per 24 hours has been regularly attained, with a conversion efficiency of 95 per cent. Without the application of external heat, the efficiency is about 85 per cent.

The first ammonia oxidation plant established in the United States on a commercial scale was installed at the Ammo-Phos Works of the American Cyanamid Company, at Warners, New Jersey, in July, 1916. The catalyzer units at that time had a conversion capacity of 14 pounds of nitric acid per hour, but improvements in design and methods have since raised this figure to 40 pounds. The catalyst is heated electrically and consists of a single fine platinum gauze having an area of about two square feet. In this catalyzer the gas mixture passes downwards through the gauze. The high efficiency obtained with this catalyzer is

FIG. 20.



Catalyzer for ammonia oxidation.

illustrated by a record for the week July 13 to 19, 1918, shown in Table XI.

At the United States Government Nitrate Plant at Muscle Shoals, nearly 700 catalyzers have been installed during the past year. Each of these consists of an aluminium box, having a cross-section of 14 in. x 28 in. and a height of 5 feet. At the base a sheet of platinum gauze weighing 143 grams is stretched at right angles to the gas flow. The gauze has 80 meshes to the inch and is made of wire 0.003 in. in diameter. Each catalyzer has an 8 kilowatt transformer, and is operated with 375 amperes at 21 volts.

At the Semet-Solvay Company's small plant, in Syracuse, N. Y., electrically heated, multiple platinum gauzes are employed.

TABLE XI.
Catalyzer No. 5.

Date.	Hour.	Conversion efficiency, Per cent.
July 13.......	2.35 A. M.	96.2
July 13.......	8.40 A. M.	98.5
July 13.......	5.20 P. M.	93.1
July 13.......	11.50 P. M.	96.0
July 14.......	5.50 A. M.	97.4
July 14.......	5.10 P. M.	94.8
July 15.......	10.35 A. M.	95.0
July 15.......	5.15 P. M.	95.8
July 16.......	1.50 A. M.	95.4
July 16.......	11.20 A. M.	95.4
July 17.......	1.10 A. M.	92.1
July 17.......	1.00 P. M.	92.3
July 18.......	12.50 A. M.	93.4
July 18.......	10.55 A. M.	92.6
July 18.......	8.00 P. M.	91.9
July 19.......	9.50 A. M.	93.6
Average for week.........		94.5

PRODUCTION, ENERGY REQUIREMENTS, COSTS.

Although ammonia oxidation plants are in operation in the United States, England, France, Germany, Italy and Russia, no information is available regarding the world's annual production of nitric acid from ammonia. It had been estimated that in the spring of this year in the United States the producing rate of nitric acid from ammonia, obtained by the fixation of atmospheric nitrogen, would be about 225,000 tons, 100 per cent. acid, per annum.

Owing to the signing of the armistice, however, it is probable that the government plant at Muscle Shoals will cease operation for a time. With the closing of this plant, there will be no nitric acid produced in this country by the oxidation of ammonia, with the exception of the small amount that is prepared from cyanamide ammonia at the Ammo-Phos Works of the American Cyanamid Company, at Warners, N. J., for operating their 50,000 ton sulphuric acid plant, and a small quantity produced at the works of the Semet-Solvay Company at Syracuse, N. Y.

The energy required for the production of nitric acid from ammonia is small. It consists of the electrical energy used in heating the catalyst, and the energy employed in operating the blowers which force the gas mixture through the catalyzer and that used in the absorption of the nitrous gases and in the concentration of the dilute nitric acid.

Owing to the high velocity of the ammonia-air mixture through the catalyzer, a comparatively large amount of ammonia can be oxidized with a relatively small catalyzer, and since the energy requirements are small, the conversion cost will be low. Estimates of this cost vary considerably, but it is probable, under normal conditions, that it is somewhat under one cent per pound of nitric acid, in the form of 53 per cent. acid. The total cost of nitric acid (93 per cent.) by the oxidation method is probably a little less than three cents per pound.

From a financial standpoint the production of nitric acid by the oxidation of ammonia can compete successfully with its production by the retort process from sodium nitrate, as the cost of conversion is about the same in both processes. Moreover, since sodium nitrate and ammonium sulphate have sold in the past at the same price per pound of nitrogen, ammonia is the cheaper form of nitrogen by the amount of sulphuric acid required to convert it into the sulphate. This, therefore, will make a difference of 15 to 20 per cent. in the cost of nitric acid, in favor of the oxidation of ammonia.

VII. COMPARATIVE DATA.

It may be of interest to compare the relative efficiencies of the arc process, the cyanamide process and the direct synthesis of ammonia, as these represent the three most important methods for the fixation of atmospheric nitrogen. By expressing coke, coal and other fuel in units of electrical energy, the quantity of nitrogen that may be fixed for a given energy consumption may be obtained. Thus, with one kilowatt year there can be fixed by the direct synthesis of ammonia, about 830 kilograms of nitrogen; by the cyanamide process, about 380 kilograms of nitrogen; and by the arc process, about 130 kilograms of nitrogen. The low energy consumption in the direct synthesis of ammonia is offset to some extent by the difficulties involved in operation, and the heavy dead charges; that in the cyanamide process by the large labor requirements and the number of operations involved. On the other hand, while the energy requirements of the arc process are high, it must be remembered that the labor involved is small, that its operation is extremely simple and that the raw materials are free.

In Table XII are given data[9] relating to investment and operation costs, per ton of fixed nitrogen, for the arc, cyanamide and direct synthesis of ammonia processes.

TABLE XII.

	Arc process.	Cyanamide process.	Direct synthesis of ammonia by	
			The Haber process.	The General Chemical Co. (De Jahn) process (*a*).
Product	35 per cent. HNO_3	NH_3	NH_3	NH_3
Investment	$1410 (*b*)	$440 (*b*)	$540	$300
Operating costs (*c*)	$170	$150 (*d*)	$119	$ 97
Product	96 per cent. HNO_3	96 per cent. HNO_3	96 per cent. HNO_3	96 per cent. HNO_3
Investment (*e*)	$1550	$670	$570	$530
Operating costs (*f*)	$220	$270	$239	$217

(*a*) Estimates on the Geneal Chemical Co. process are based on war time construction costs. All others on normal prices.
(*b*) Power plant investment reckoned at $100 per horse power.
(*c*) Amortization for cyanamide as charged by operating companies. Amortization for Haber 20 per cent. of plant cost for repairs, interest and depreciation. Amortization for Arc and Modified Haber 12.5 per cent. for interest and depreciation. $5.00 per ton of product for repairs.
(*d*) Cyanamide production $122, ammonia from cyanamide $28, total $150.
(*e*) Except for Arc process, includes ammonia plant as given; power additional, $10; oxidation and absorption, $140; concentration, $40; steam plant, $40.
(*f*) Except for Arc process, includes ammonia costs as given; oxidation, $50; concentration, $70. No allowance made for unoxidized ammonia.

During the past five years rapid progress has been made in the fixation of atmospheric nitrogen, especially by the cyanamide process and by the direct synthesis of ammonia. As a result of this advance, greatly stimulated by the war, nearly one-third of the nitrogen used by the Allies for military explosives in the autumn of 1918 was obtained from the atmosphere. That the nitrogen problem has been solved is attested by the following data showing the progress of the nitrogen industry:

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[9] Nitrate Supply Committee Recommendations, *J. Ind. Eng. Chem.*, **9**, 841 (1917).

ANNUAL PRODUCING CAPACITY IN TONS OF NITROGEN.

United States:	1914	1918 (Autumn)	1919 (Spring) (estimate)
Cyanamide	0	46,000	91,000
Synthetic ammonia	0	9,000	9,000
Total atmospheric nitrogen	0	55,000	100,000
By-product ammonia	38,000	90,000	100,000
Grand total	38,000	145,000	200,000
The World:			
Cyanamide	53,000	265,000	343,000
Synthetic ammonia	12,000	109,000	109,000
Arc process nitrogen	10,000	15,000	15,000
Total atmospheric nitrogen	75,000	389,000	467,000
By-product ammonia	300,000	350,000	360,000
Sodium nitrate	430,000	500,000	520,000
Grand total	805,000	1.239,000	1,347,000

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DEPARTMENT OF CHEMISTRY,
SWARTHMORE COLLEGE,
SWARTHMORE, PA.
March 26, 1919.

Speculum Metal. ANON. (*Brass World*, vol. xv, No. 5, p. 147, May, 1919.)—If two parts of copper and one of tin are mixed, it makes a white alloy which has a brilliant lustre, and will take a high polish. This alloy is known as speculum metal, the technical name for telescope mirrors or reflectors. The addition of one or two per cent. metallic arsenic makes the metal more compact and gives it a greater lustre and hardness, but renders it liable to be tarnished. It is nearly as hard as steel and as brittle as sealing wax.

Qualities of Steel for Guns. ANON. (*Machinery*, vol. xxv, No. 9, p. 835, May, 1919.)—The metallurgy of gun steel has been greatly altered as a result of the war. As the war drew to a close, steel for large guns was being made in a radically different manner than had ever been thought possible. It was an accepted fact four years ago that only acid open-hearth steel could be safely incorporated in ordnance guns, and the plants especially built in this country adopted this process. The reason for this policy was that it is possible by this process to make unusually pure and reliable metal, and it was thought that this was the only method by which this was possible. The great disadvantage involved is the length of time to produce a heat of such steel. In all such work the complete deoxidation, the formation of the proper slags, and the refinement of the metal consume from thirteen to fifteen hours in the case of a forty- or fifty-ton heat with the utmost care necessary. As the development of the ordnance program progressed, it was found that the large electric furnace refining hot metal on a basic bottom produced gun steel equal if not superior to that made by the long-drawn-out acid open-hearth process.

While a three per cent. nickel steel was the standard alloy incorporated in many of the guns, it is stated that at a large British plant a plain carbon electric steel was giving entire satisfaction in the last months of the war. It is also reported that in one American plant gun steel that met ordnance specifications satisfactorily was being made in basic open-hearth furnaces—a steel that was tabooed for guns before the war and later. It is probably a fact that had the war continued much longer, the electric furnace would have been the first selected as the agent with which to make ordnance steel. It was even being scheduled for one of the later plants, and this is so, not so much perhaps because of the superiority in quality over acid open-hearth, but because the same amount of suitable metal can be made in about one-third the time.

Vegetable Oils. ANON. (*The Chemical Engineer*, vol. xxvii, No. 2, p. 30, February, 1919.)—Government restrictions on the export of vegetable oils, coupled with what is apparently an overproduction of oil, the result of the stimulus of war-time conditions and prices, has resulted in the production of a paradoxical condition in the industries producing or handling vegetable oils. While there is a strong demand for fats of all kinds over wide areas in Europe, with good prices offering, the American market is glutted with vegetable oils. Not only is this condition of affairs causing American dealers and manufacturers a great deal of inconvenience, but the holders of large stocks of raw and refined oils are threatened, if the present condition of affairs continues for any length of time, with serious losses through the deterioration of the oil. Further, according to those well acquainted with the situation, there exists a very real danger that the existing export market for American surplus oil and oil products may be lost during the period over which the import restrictions hold good.

AN APPLICATION OF THE RADIOMETER TO THE MEASUREMENT OF ELECTRIC CURRENT.*

BY

THOMAS D. COPE, Ph.D.

Assistant Professor of Physics, University of Pennsylvania.
Member of the Institute.

THE radiometer was discovered by Crookes[1] about 1875, and was used by him to measure radiant energy. In 1883 Pringsheim[2] applied a form of the instrument to the study of the infra-red spectrum of the sun. In 1897 E. F. Nichols[3] produced the first highly sensitive and accurate radiometer. He applied it to the study of the transmission and reflection of radiation by quartz, and subsequently to the study of radiation received upon the earth from planets and fixed stars. Nichols and Hull[4] applied the radiometer to the study of light-pressure. Stewart[5] has applied the instrument to the study of radiation from acetylene flames. Drew[6] has used it to measure the energy radiated from vacuum-discharge tubes. Coblentz has reviewed measurements of radiation made by himself and others, together with the significant facts about the instrument in the Bulletin of the Bureau of Standards, vol. iv, No. 3.

The suggestion to apply the radiometer to the measurement of electric current was made by Dr. C. E. Hiatt, formerly Harrison Research Fellow in Physics at the University of Pennsylvania. To try out his suggestion he constructed a radiometer with two vanes, each of which faced a thin metallic strip which was connected by electric leads to binding posts outside of the vacuum chamber. Each strip when heated by the passage of

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* Communicated by the Author.

[1] *Phil.Trans.* (II), **166**; p. 325, 1876.

[2] *Ann der Phys.* (3), **18**; p. 32, 1883.

[3] *Phys. Rev.,* **4**; p. 297, 1897.

[4] *Phys. Rev.,* **13**; 1901; p. 307.

[5] *Phys. Rev.,* **13**; 1901; p. 257.

[6] *Phys. Rev.,* **17**; 1903; p. 321.

current through it would, it was thought, repel the vane facing it. The geometrical relations of heaters and vanes were such that the torques applied to the radiometer suspension by the heaters would be oppositely directed. If the two heaters were joined in series and a current were sent through them a " zero " position of the suspension would be established. If then a current of unknown strength were sent through one heater and an easily measurable current were sent through the other and the latter were varied in intensity until the suspension should assume its zero position the intensity of the known current would equal the effective value of the intensity of the unknown.

As Doctor Hiatt was prevented from continuing the investigation the radiometer was turned over to the writer by Professor A. W. Goodspeed with the suggestion that the work be continued. The instrument as first designed was found after repeated tests to be unsatisfactory. It was abandoned and a new form was designed and constructed, as described in the following:

A glass vessel was blown approximating a right circular cylinder with rounded convex ends. It was 30 centimetres long and 10 centimetres in diameter. When in use it stood with its axis vertical. It was provided with four orifices. One of the latter, coaxial with the vessel at the bottom, led through a stopcock and ground-joint to a von Reden pressure gauge and through a drying-vessel which contained phosphorus pentoxide to a Geissler air-pump. A ground-joint coaxial with the vessel at the top, 16 millimetres at its greatest diameter, admitted a ground stopper which was prolonged into a rod 4 centimetres long from which the radiometer was suspended. The other two orifices were coaxial ground joints. Their common axis was a prolonged diameter of the vessel, distant approximately 14 centimetres from the top. These joints tapered from an exterior diameter of 3.6 centimetres to a diameter of 3.3 centimetres where they entered the vessel. Each was 4 centimetres long. Each was provided with a hollow stopper provided with a handle. Through the stoppers were sealed platinum leads. Each stopper supported a mica frame which carried a current-bearing heater. To the top of the vessel was attached externally and coaxial with it a horizontal disk 6 centimetres in diameter whose limb was graduated in degrees. Over this circular scale moved a pointer rigidly attached to the stopper in the upper ground joint.

The radiometer suspension was supported by a quartz fibre 9 centimetres long and one-seventieth of a millimetre in diameter. It hung along the axis of the containing vessel from the glass rod, to which it was attached. It supported a small stirrup which in turn held a horizontal aluminum wire 9 centimetres long and 0.5 mm. in diameter. To this wire were attached, each in the vertical plane through the wire, centrally a light wire carrying a circular plane mirror about one centimetre in diameter, and flush with each end a rectangular vane of mica, 3.5 cm. horizontally by 3 cm. vertically.

The heaters were wound on opposite faces of vertical mica frames. Platinum wire 0.1 mm. in diameter was used. The frames were supported in the lateral ground stoppers. Each heater faced a vane of the suspension in such a way that the turning moments given to the suspension by the two heaters were similarly directed. The area of a vane was somewhat greater than the area covered by the heater which it faced. The heater wire was soldered to copper leads which in turn were soldered to platinum leads through the glass. The two heaters were joined in series in circuit with a storage cell, an adjustable resistance and a Siemens and Halske milliameter. The circuit was connected to the water pipe system of the building to remove possible static changes.

The instrument was supported by appropriate stands and clamps and was protected from external radiation by close-fitting card-board shields packed with cotton and covered externally by a sheet of tinfoil. It was mounted in a recess in the wall and protected from daylight by a system of curtains. A vertical section of the apparatus is shown in Fig. 1.

Readings were made by means of the following arrangement: A millimetre scale was placed horizontal, and parallel to the mirror approximately 45 centimetres from it. Beneath the scale was placed a vertical slit illuminated by a 2-volt miniature lamp. A lens of 40-cm. focal length, 40 cm. from the scale, threw an image of the slit reflected from the mirror of the suspension upon the scale. A null method was used in making measurements. The readings taken when current flowed through the heaters were the number of degrees through which the torsion head of the instrument had to be turned to bring the suspension to its position of equilibrium when no current was flowing in the heaters. This position was indicated by a chosen "zero position" of the image of the slit on the scale.

Measurements were made with the instrument for the purpose of determining the pressure at which the sensibility was a maximum. Readings were taken of the deflections arising from currents of 5, 10, and 15 milliamperes in the heaters at pressures ranging from 1 mm. to 0.01 mm. The order of readings was 0, 5, 10, 15, 10, 5, 0 milliamperes. A table of data and a curve showing the results of this investigation are given in Table I and Fig. 2. This investigation shows the existence of a pronounced maximum of sensibility at a pressure between 0.03 and 0.035 mm. of mercury. Several sets of readings all leading to the same

Fig. 1.

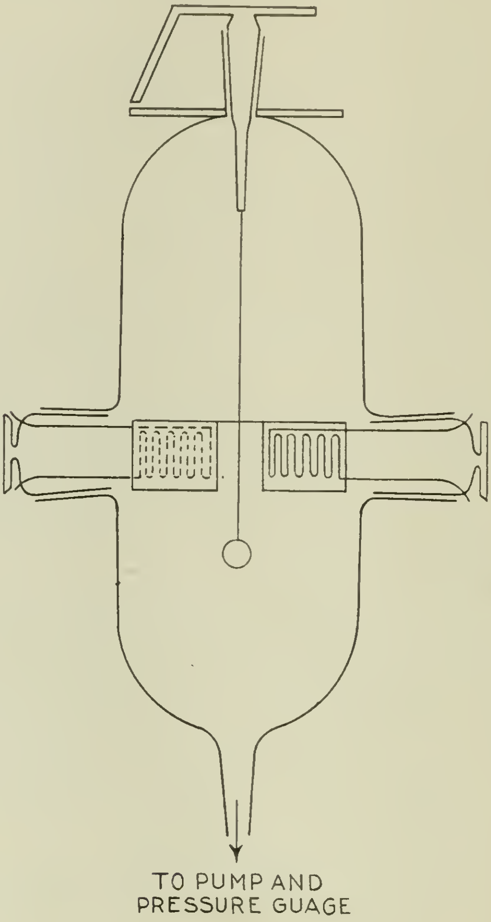
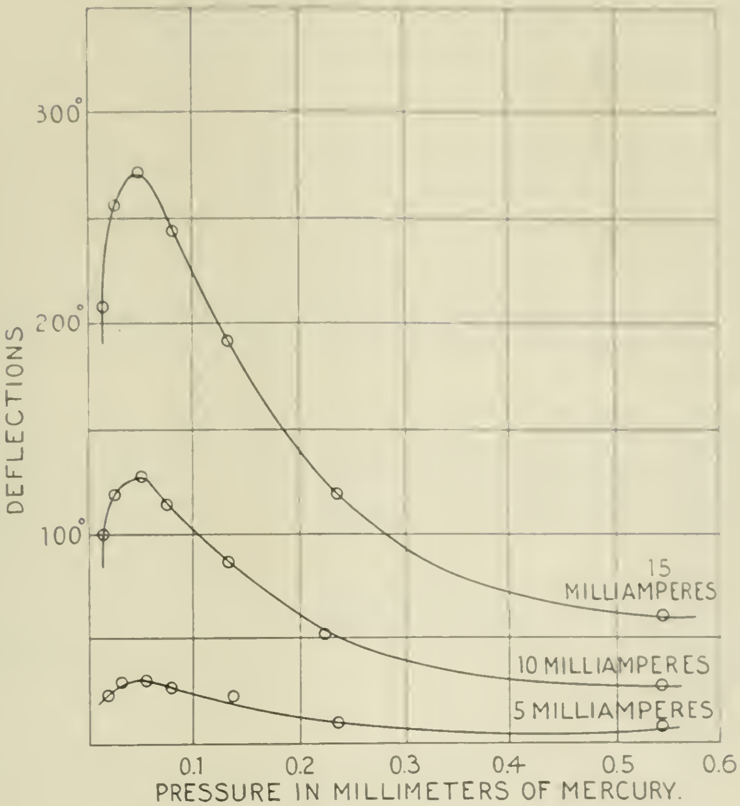


FIG. 2.



result were taken. The set given was the final and most satisfactory one.

TABLE I

Pressure (m.m.)	Deflection (degrees on torsion head)				
	5	10	15	10	5 milliamperes
2.08	. . . .	7	16	7	1.5
1.07	4	15.5	34	16	4
0.544	6.5	27.5	61	29	7.5
0.235	12	52	117	52	12
0.131	23	84	193	85	23.5
0.0697	26	111	245	111	26
0.0381	31.5	125	272	125.5	31
0.0187	31	120	265	121	31
0.0185	29.5	117.5	255.5	119.5	29.5
0.0096	24	100	207	99	25

In the region of maximum sensibility the instrument was calibrated. The pressure used was 0.0378 mm. of mercury. Readings were taken of the current in the heaters and the deflection of the vanes for currents rising by approximate steps of 2 milliamperes from zero current to 17.15 milliamperes and decreasing by the same steps. A table is given showing a set of observations, together with a curve in which square roots of deflections are plotted against currents.

FIG. 3.

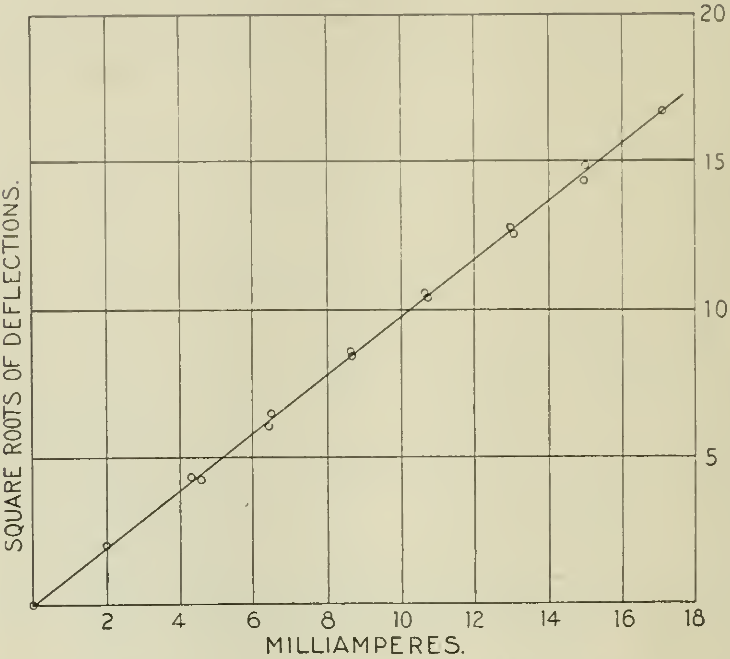


TABLE II

Pressure 0.0378 millimeters		Square root of deflection
Current (milliamperes)	Deflection (degrees)	
2.0	4	2
4.25	18	4.24
6.4	37.5	6.12
8.7	71	8.42
10.9	111	10.5
13.0	157	12.5
15.1	212	14.5
17.15	275	16.6
15.1	220	14.8
13.0	159	12.6
10.8	113	10.6
8.7	72.5	8.51
6.5	42	6.48
4.3	17.5	4.18
2.0	4	2

Since the same geometrical relations existed between the heaters and the vanes facing them when readings were taken, the amount of energy falling upon the vanes depended only on the rate at which it was liberated in the heaters. The fact that the curve is a straight line shows that the turning moment upon the radiometer suspension is directly proportional to the energy which falls upon the vanes. This principle has been established by previous investigators in a number of ways. It is believed that the device of liberating the energy from electric heaters within the vacuum space has not been employed heretofore to establish this principle.

An attempt was made to increase the sensibility of the instrument by blackening the faces of the vanes adjacent to the heaters with camphor smoke. Readings were made at a pressure of 0.0297 mm. as follows:

TABLE III

Current in milliamperes	Deflection in degrees
5	29
10	115
15	243
10	116
5	30

These deflections are of the same order of magnitude as those obtained under like conditions with unblackened vanes, and show no rise in sensibility arising from the blackening. Measurements made of the resistance of the two heaters in series when currents of various intensities were flowing through them gave the following results:

Resistance of heaters	Current in heaters
14.54 ohms	0.6 milliamperes
14.56 ohms	15.0 milliamperes

In conclusion, there is to be pointed out the possible usefulness of the principle employed in this instrument in an indicator of effective values of currents of rapidly varying direction and intensity. Its use in circuits containing spark gaps in which the added resistances of the heaters would be apprciable is suggested. The instrument is usable only when thoroughly shielded from radiation and mechanical vibration. In common with other hot wire instruments it has the disadvantages of a complicated construction and rather sluggish action in reaching its final reading.

It was the plan of the writer to redesign the apparatus with a view toward determining the effective values of currents of unknown intensity by balancing the torques given by them to the radiometer suspension by the torques arising from direct currents of known intensity. At this stage the work was interrupted and opportunity to continue it has not since existed.

RANDALL MORGAN LABORATORY OF PHYSICS,
UNIVERSITY OF PENNSYLVANIA.

A New Seed Oil from Cockle Burr. L. B. RHODES. (*American Chemical Society News Service, Bulletin No. 231,* May 4, 1919.)—Out of the cockle burr which sticks to the clothes of the passer-by and has generally been considered a pest, is now being made a new and valuable oil available for use in paints and varnishes and adapted for food. The "cockle-burr," familiarly known as the "clot-burr," is a coarse plant with rough leaves and prickly head. It is widely distributed through the United States so that it is more or less of a nuisance in most localities, and is very abundant throughout the South. If the burrs could be obtained systematically in sufficiently large quantities, they could be easily milled.

Those which were gathered were either dry or in a half-dry condition. They were first cut in half by a trimming board and the kernels mashed. They were then placed in a box and vigorously shaken. The hulls were taken out, leaving the kernels at the bottom. These kernels were then pounded and rubbed in a mortar until the black shucks were removed after which the husks were forced out by blowing. The ground kernels were then wrapped in cheese cloth and pressed between cold steel plates. The oil thus obtained was allowed to settle for three or four days and then filtered. It is of a light yellow shade; has a clear sparkling appearance and a pleasant odor and an agreeable nutty taste. It keeps well without becoming rancid. On account of this quality it should eventually be used as a substitute in the dietary for other vegetable oils. The press cake left after expressing the oil should be of value as a food for cattle and certainly it can be readily used as a fertilizer.

There seems no doubt that before long the cockle burr oil should find a place in commerce because of the richness of the kernel and ease with which the oil can be extracted. The yield from the kernel is about 30 per cent. and the kernels constitute about the same proportion of the bulk of the crude burrs. The press cake contains 40.34 per cent. of protein. With such in their favor the familiar roadside pests may prove of real service to both man and beast.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

NEW FORMS OF INSTRUMENTS FOR SHOWING THE PRESENCE AND AMOUNT OF COMBUSTIBLE GAS IN THE AIR.[1]

By E. R. Weaver and E. E. Weibel.

[ABSTRACT.]

A STUDY has been made of the combustion of small amounts of gas in the air at the surface of electrically heated wires and the application of this phenomenon to the design of instruments for the purpose of detecting the presence and indicating the amount of combustible gas in the air. As a result of this study three types of instruments, each especially adapted to certain uses, have been designed, tested, and found to work satisfactorily.

The action of one of these instruments depends upon a resistance change, one upon a heating effect upon an adjacent bimetallic strip, and one upon the light emitted from the heated wire.

A discussion of the principles involved in the design of the instruments and specifications for their construction are given.

SPECIFICATIONS FOR AND METHODS OF TESTING SOAPS.[2]

[ABSTRACT.]

THIS circular includes a general discussion of the composition of soap and the varieties of toilet, laundry, scouring and soft soaps for which specifications are proposed. These specifications cover milled toilet soap, white floating soap, liquid soap, shaving soap, salt-water soap, special-grade laundry soap, ordinary-grade laundry soap, chip soap, soap powder, hand grit soap, scouring soap (A), scouring soap (B) and automobile soap. The methods described include those for sampling deliveries, for preparation of the laboratory sample and for the following tests and determinations: Matter volatile at 105° C.; free alkali or acid; alkali as alkaline salts; silicate; sulphate; matter insoluble in water

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* Communicated by the Director.

[1] Scientific Papers, No. 334.

[2] Circular No. 62, 2d edition.

(insoluble siliceous material); unsaponified saponifiable matter; preparation of total fatty acids; titer test; acid number of fatty acids; total alkali; chloride; rosin; total anhydrous soap; sugar (qualitative test); feldspar and quartz; potash and soda.

EFFECT OF SOLAR RADIATION UPON BALLOONS.[3]

By Junius David Edwards and Maurice Blaine Long.

[ABSTRACT.]

This paper describes briefly the effect of solar radiation upon balloons and includes experimental measurements on typical balloon fabrics.

Preliminary to the subject proper a summary is given of the characteristics of solar radiation and atmospheric conditions which have a direct relation to the problem. The radiation characteristics of the fabrics themselves are discussed. A series of measurements on representative balloon fabrics showed an absorbing power for solar radiation varying from 45 to 90 per cent.

The fundamental relations governing the temperature of balloon fabrics when exposed to solar radiation are outlined and the application of these to the calculation of balloon temperatures is discussed. The multiplicity of factors involved makes the calculation of such temperature of very limited value, but by means of measurements on a model balloon the magnitude and distribution of the temperatures involved, in both gas and fabric, are well illustrated. The temperature of the upper surface of the model balloon in bright sunlight under certain definite conditions, varied from 20° C. to 39° C.

The importance of the radiation characteristics of fabrics in governing buoyancy changes, in causing increased permeability of the fabric to hydrogen and in its effect on the life of the fabric is emphasized as a factor in the selection of fabrics for various purposes. Other factors affecting the selection of fabrics are summarized and their relation to the radiation characterisics is pointed out.

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[3] Technologic Papers, No. 138.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

REFINEMENTS IN SPHEROMETRY.[1]

By G. W. Moffitt.

THE shortcomings of the ring spherometer are discussed and a new type of contact ring with selected ball bearings for contact members, giving greater precision and reliability, is described. A modified instrument having but one contact is also described. It has certain advantages in some cases.

The auto-collimating method, as often used, is limited in its precision because of the depth of focus of the optical system. The improvement described consists in placing the lens on a nodal slide and adjusting until lateral motion of the image in the field of view is no longer noticeable when the slide is rotated through an angle. In the caustic curve methods use is made of the aberrations introduced on oblique reflection from a spherical surface. By measuring the distance from the primary to the secondary image and multiplying by a factor depending upon the arrangement of the apparatus the radius is determined with high precision for concave surfaces or convex surfaces of short radius. This method is especially valuable when the element of surface is small.

Surfaces measured with precision by the various methods described, are as follows: (1) Mechanical Methods: Concave and convex surfaces of short and medium radius, the precision decreasing rapidly as the radius becomes larger. (2) Auto-collimating Method: Concave and convex surfaces of short or medium radius up to the limit of the slide on the turntable, the precision being high and practically independent of the radius. (3) Caustic Curve Methods: Concave surfaces of any radius to a high degree of precision, even when the element of surface available is too small to be measured by other methods. Convex surfaces of short and medium radius to a degree of precision decreasing with increased radius.

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* Communicated by the Director.

[1] Communication No. 78 from the Research Laboratory of the Eastman Kodak Company, published in *Physical Review*, vol. xiii, No. 4, p. 261.

Standardization of Aircraft Materials and Parts. ANON. (*Journal of the Society of Chemical Industry*, vol. xxxviii, No. 8, p. 144, April 30, 1919.)—It may not be generally known that during the past year and a half the British Engineering Standards Association has been responsible for the preparation of all specifications for aircraft materials on behalf of the Department of Aircraft Production. Particularly interesting have been those specifications dealing with materials which formerly were perhaps not considered as being of an engineering nature, such as chemicals used as ingredients for aeroplane dope, rubber, textiles, adhesives, paint and varnishes. Owing to the extremely useful part these specifications have played it is now learned with considerable satisfaction that the British Engineering Standards Association has been requested to continue to prepare them as well as to undertake their distribution, together with the issue of manufacturing instructions and notes on testing procedure which were formerly prepared and issued by the Technical and Inspection Departments of the Department of Aircraft Production. The Association has undertaken this additional responsibility as from March 31, 1919.

Phenol. A. G. PETERKIN. (*Journal of Industrial and Engineering Chemistry*, vol. xi, No. 5, p. 475, May, 1919.)—Before the war this country's consumption of phenol was about 9,000,000 pounds per year. The bulk of it came from England, and was obtained from coal-tar distillates directly. A small part was synthesized from benzol. The general impression here is that this synthetic phenol was made in German plants subsidized by the Government. The production in the United States during the war increased continually. At the time of our entry into the struggle it amounted to 75,000,000 pounds per year, and after that time plants were erected so that at the end we were able to produce more than 150,000,000 pounds. Of this, not more than 2,000,000 pounds were obtained directly from coal-tar distillates by extraction with caustic soda.

At the present time the consumption in this country is not much greater than 6,000,000 pounds per year, about equally divided between the drug and disinfectant, the dyestuff, and the synthetic resin industries.

Composite Ships. ANON. (*Marine Review*, vol. xlix, No. 6, p. 283, June 1919.)—The first Norwegian composite ship has been launched at Larvik. It is built of fir planks over a steel frame, has a carrying capacity of 650 tons and a speed of nine knots. It is driven by an oil motor and can carry a fuel supply to last twelve days. Another similar ship was launched in March. Denmark has a composite ship which was built recently at Frederickshavn.

NOTES FROM THE LABORATORY, GENERAL ELECTRIC COMPANY.*

A NEW METHOD OF DEVELOPING "GUM" PRINTS.

By C. S. Ferguson.

I believe the usual method for developing prints by the gum-bichromate process, particularly when it is desired to emphasize certain features, is to gently abrase the part intended to be accentuated by means of a camel's hair brush.

This procedure, as is well known, is likely to remove entirely the delicate film of gum unless extreme caution is exercised coupled with considerable manipulative skill.

I have found, I believe, a new technic which reduces manipulative skill to a minimum and which, at the same time, allows of local development to any desired degree without showing any obvious local treatment.

The print is first soaked in warm water. It is then supported against a piece of stout cardboard, as an easel, and sprayed with warm water from an atomizer. By having an ordinary photograph as a guide, one can so control the development of the image as to meet one's standard of art.

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* Communicated by the Director.

The "Pipeless" Furnace. Anon. (*Metal Worker, Plumber and Steam Fitter,* vol. xci, No. 19, p. 519, May 9, 1919.)—The so-called "Pipeless" furnace, by which the heating of an entire dwelling is effected through only one outlet on the first floor immediately above the furnace, has come into extended use within recent years. The very satisfactory results of the one-pipe apparatus are due to a double cased furnace with a duplex register face for the entrance of cool air as well as for the discharge of heated air. Equally good results can be obtained from the same furnace with the old style casing and independent registers and ducts for warm and return air supplies.

The success of any warm-air heating apparatus depends on the proper circulation of the air in the space warmed. If the air in such space is not moved or replaced, there will be no warm air flowing from the registers. While there are very many apparently successful furnace plants, their economy is below par. This fact is demonstrated when a return air supply is installed. The return air system practically accomplishes exactly what the "pipeless" does. Such a condition is often found and disposes of the usual argument for more cold air. It also proves that some means must be provided for properly circulating the air to secure satisfactorily warm air plants.

The temperature at the register face of the one-pipe furnace is considerably higher than the ordinary register, and the velocity of the entering air is greater than from the common form of warm-air pipe. The high temperature and velocity combine to make the heating of almost any open or connected space a simple, quick and positive operation. Rooms on the second floor will be warmed so long as the doors are kept open, although distant rooms will suffer unless they open from a general hallway. The "pipeless" furnace supplies a need that has long existed for a simple and economical method of heating that does away with the objection of stoves, but it does not replace the desirable qualities of a good warm-air plant, properly piped and supplied with air, both from the house and from out of doors.

Department Store Testing Laboratory. ANON. (Dry Goods Equipment Through *Philadelphia Public Ledger*, May 9, 1919.)—What is probably the first research laboratory to be put in by any department store in the United States has been installed recently by the Bannon Brothers Company, St. Paul, Minn. This laboratory, completely equipped, and on the main floor in the textile department, actually makes practical and chemical tests of the textiles, food products, linoleums and other goods carried by the store. This has two advantages—it enables the buyers to know that the goods they buy are up to specifications with respect to quality, materials, and freedom from adulteration, and it enables the store to advertise its goods under a quality guarantee, backed by the evidence of its own laboratory.

The research laboratory consists of a glass-inclosed room, fitted out with the usual chemical laboratory equipment and in addition with special equipment for the testing of textiles and other products. The staff includes a trained chemist and two assistants, who make analyses of goods. Both microscopical and chemical tests are used. For accurate work in analyzing cloths the chemical test is necessary, but quick determinations that give approximate values can easily be made with a microscope.

The object of the laboratory is honesty in merchandising. The customer's interests are protected by checking and analyzing goods to see that they are as they are represented and that no misleading statements are made, especially in the papers. A test is made of every article advertised so that it can be truthfully presented as "pure silk" or "89 per cent. wool" with the backing of an actual test in the store's own laboratory.

NOTES FROM THE UNITED STATES BUREAU OF CHEMISTRY.*

PHOTOSENSITIZING DYES.

[ABSTRACT.]

THE photosensitizing dyes, *pinaverdol* and *pinacyanol*, which are used in the manufacture of panchromatic and orthochromatic plates, and which before the war were made exclusively in Germany, have now been synthesized in this country. The syntheses of these dyes, which are quinoline derivatives, are described in an article [1] by Wise, Adams, Stewart, and Lund, of the Color Laboratory of the Bureau of Chemistry. Two articles [2] describing the synthesis of the intermediates required for the formation of these dyes are published in the same issue of the same journal.

PARA CYMENE: II. THE UTILIZATION OF CYMENE FOR THE PREPARATION OF PHOTOGRAPHIC DEVELOPERS.[3]

By H. A. Lubs.

[ABSTRACT.]

LABORATORY methods for the production of para-amino-carvacrol have been worked out. This compound has been found to be very useful as a photographic developer. It is more satisfactory than para-amino-phenol, and while not quite so good as para-amino-cresol or " metol," so far as lasting quality of the bath is concerned, it is equally good with respect to quality of tones secured in the final prints.

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* Communicated by the Chief of the Bureau.

[1] *J. Ind. Eng. Chem.*, **11**: 460, May, 1919.

[2] *J. Ind. Eng. Chem.*, **11**: 456, 458, May, 1919.

[3] Published in *J. Ind. Eng. Chem.*, 11: 455, May, 1919.

Domestic Electric Appliances. ANON. (*Electrical Review*, vol. lxxiv, No. 20, p. 808, May 17, 1919.)—Never before in the history of the electrical industry has there been such activity in the field of domestic electrical appliances as exists to-day. Practically all manufacturers report that their plants are working to capacity and central stations and dealers are doing an unusually large volume of business.

The reasons for this condition are obvious. In the first place the electrical appliance has become a household necessity. Also, the serious shortage in domestic labor has greatly stimulated the use of labor saving devices, as have the higher standards of living on the part of all classes of labor. Finally, central stations and dealers have made special effort to secure this class of business, especially since the restrictions were put into effect on practically all other business.

The saturation point is still far distant and efforts should be redoubled to increase the use of appliances under the favorable conditions existing to-day.

Applying the Brakes in Starting a Car. ANON. (*Electric Railway Journal*, vol. liii, No. 20, p. 964, May 17, 1919.)—One line of an electric railway was experiencing considerable trouble due to the blowing of circuit breakers. There were no excessive grades on this line and engineers of the company were somewhat puzzled to find a reason for such a phenomenon on one line while everything was apparently satisfactory on the others. Accordingly a man was detailed to watch the operation of the cars.

He discovered that there was a section of track which was very slippery and that the motormen had trouble in starting the light-weight cars at this point. They had received instructions to accelerate rapidly, which to them meant operating the controller rapidly. On this particular section of track it was the practice to notch up the controller very fast, and when the slipping point of the wheels had been reached to apply the brakes to keep the wheels from slipping. The reverse of this method was also found to have been applied in stopping the cars. The brake application produced a very rapid rate of retardation, and when the slipping point of the wheels was reached power was applied to prevent the wheels from skidding.

Petrol Substitute. ANON. (*The Iron Trade Review*, vol. lxiv, No. 21, p. 1355, May 22, 1919.)—Owing to the shortage of petrol in Greece consequent on the Allied blockade in 1916, a new petrol substitute was put on the market. It was composed of 80.90 per cent. of pure turpentine, distilled from resin from the pine forests of Greece, and 10.20 per cent. ether, which was also produced from native sources. The fuel was expensive and deposited a comparatively large amount of carbon in the cylinders, but this was easily removed.

NOTES FROM THE UNITED STATES BUREAU OF MINES.*

Vanadinite.—Experiments on the metallurgical treatment of vanadinite, with the object of recovering vanadium and lead, have been completed by the Golden Station of the Bureau. The arc furnace method was used to prepare ferrovanadium from calcium vanadate, containing only 16 per cent. of V_2O_5. Reductions made with aluminum gave better results than with silicon.

Ammonia in Producers.—A report on the quantity of ammonia in producers of the Smith type has been completed by the Seattle station. The use of Illinois coal in water-gas plants for producers of coal gas benches was studied at Rockford, Illinois. It was found that the use of this coal was an economy, although more coal was consumed per ton carbonized, smaller and more frequent changes are required and more attention is necessary than with coke as a fuel.

Oil Shale.—A bibliography of oil shale has been completed by the San Francisco Field Office. The work of collecting the data relative to the production and decline of the oil fields of California has been completed.

Geophone.—A study of the geophone, as developed for war purposes, to determine its applicability to surveying and mine rescue work in metal mines, was made at Franklin, N. J., in the mine of the New Jersey Zinc Company. Further work is being conducted at the Experimental Mine at Pittsburg on the instrument, which gives promise of value in mining not only in locating men entombed underground, but also as a warning to breaking through in a heading; in determining the direction underground of connections at drifts, tunnels, and raises without the use of survey instruments; for use in surveying diamond drill holes; for the location of underground water courses; and for use in counting shots fired underground. It has been found that sound is transmitted better through rock than through coal.

Mine Fires.—Valuable assistance has been rendered by the Bureau of Mines cars at recent mine fires. On March 4, in response to a call from the Hebron Fire and Pressed Brick Co.,

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* Communicated by the Director.

Hebron, N. D., that they were unable to control a fire which threatened their lignite coal mine, Car 5 proceeded immediately to the place. The Bureau men wearing mine rescue apparatus were able to seal the fire, and possibly saved the mine. In a preliminary report the engineer in charge, Mr. Dyer, stated that there was a large German population at this place who were greatly impressed with the kindness of the government in thus aiding them.

On March 18 the Chamber of Commerce of Richey, Montana, wired that a fire in a local mine was beyond control and threatened their local coal supply and appealed for aid. Mr. B. W. Dyer was ordered to Richey. A letter of appreciation of the assistance given has been received from the Richey Chamber of Commerce. On February 25 a serious coal mine fire broke out at Somerset, Colo., and in response to call the engineer and Car 2 were sent there. On March 28 a serious fire broke out in the Argonaut Mine, near Jackson, Cal. Car 5, with District Engineer Wolflin, proceeded at once to the scene. No lives were lost, and serious property damage was prevented by quick action. On March 31, thirteen men were entombed and killed at an explosion at the Empire mines, Aguilar, Colo. Car 2 responded to the call.

Mine Rescue Cars.—The three new Bureau of Mines rescue cars, construction of which has been delayed on account of war conditions, will soon be completed. One of the cars will be ready by May 15 and the remaining two by July 1. These cars are to be stationed at Terre Haute, Ind.; Ironwood, Mich.; and Rock Springs, Wyo. The cars are to be of the new model and well equipped in every way.

THE FRANKLIN INSTITUTE.

(Proceedings of the Stated Meeting held Wednesday, May 21, 1919.)

Hall of The Franklin Institute,
Philadelphia, May 21, 1919.

President Dr. Walton Clark *in the Chair.*

By consent of the meeting the reading of the minutes of the previous meeting was dispensed with.

Additions to membership since last report: 1.

The chairman announced that the business of the meeting would be the annual presentation of The Franklin Medal, the Institute's highest award, in recognition of distinguished scientific and technical achievements, and called upon Dr. Harry F. Keller, who gave an account of the work of Sir James Dewar, of the University of Cambridge, and the Royal Institution, London, recently recommended by the Institute's Committee on Science and the Arts for The Franklin Medal in recognition of "His numerous and most important contributions to our knowledge of physical and chemical phenomena, and his great skill and inventive genius in attacking and solving chemical and physical problems of the first magnitude."

Doctor Keller then presented Major General James Douglas McLachlan, C.B., D.S.O., representative of His Britannic Majesty's Government, who received the medal for Sir James Dewar, and conveyed the thanks of his Government and of the recipient for the honor conferred upon him.

Doctor Keller was again recognized and described the work of Major General George Owen Squier, who had also been recommended for the award of The Franklin Medal in recognition of "His valuable contributions to physical science, his important and varied inventions in multiplex telephony and telegraphy and in ocean cabling, and his eminent success in organizing and directing the air and signal services of the United States Army in the World War," and introduced Dr. F. P. Keppell, Assistant Secretary of War, who, in the absence of Major General Squier, received the medal on behalf of the recipient and the War Department.

Colonel C. McK. Saltzman, Acting Chief Signal Officer, United States Army, then read a paper, entitled "Some Aspects of the Signal Corps in the World War," which had been prepared by Major General Squier for presentation on this occasion.

Lantern slides and moving pictures showing the activities of the Signal Corps with the American Expeditionary Force were shown, as well as various Signal Corps communicating devices.

Adjourned.

R. B. Owens,
Secretary.

(A full account of the meeting will appear in the next issue.)

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of the Stated Meeting held Wednesday, May 7, 1919.)

Hall of The Franklin Institute,
Philadelphia, May 7, 1919.

Mr. Benjamin Franklin *in the Chair.*

The following report was presented for final action:

No. 2728: Landreth's Electrolytic Sewage Process. Recommended that the Howard N. Potts medal be awarded to Clarence P. Landreth, of Philadelphia, Pa.

R. B. Owens,
Secretary.

ANNUAL REPORT OF THE DIRECTOR OF THE SCHOOL.

1918–19.

COURSES OF INSTRUCTION.

The ninety-fifth year of the Franklin Institute School of Mechanic Arts closed May 2, 1919. During the year instruction was given in Mechanical Drawing, Architectural Drawing, Shop Arithmetic and Algebra, Plane Geometry and Trigonometry, Applied Mechanics and Strength of Materials, and Naval Architecture.

REGISTRATION.

The total registration for the year was four hundred seven individual students, approximately the same as the enrollment of the previous year. The call of their country to service in the World War prevented many former students from continuing their courses during the past year.

ATTENDANCE AND PROGRESS.

For the first term twenty-three students had a perfect attendance record, and fifty-three had a perfect attendance record during the second term. In the regular school work twenty-seven students made an average of 90 per cent. or over during the first term, and thirty an average of 90 per cent. or over during the second term.

The work of the school was seriously interrupted in the early part of the year by the influenza epidemic. Also, much of the time of the students was taken up by the unprecedented activity of the industrial plants in which a majority of them were employed, and this prevented them from attending their classes regularly. Considering these handicaps, the high averages in class work and attendance records indicate that the School of Mechanic Arts has completed a successful year.

FACULTY.

The corps of Instructors consisted of men of practical experience in the work in which they instructed and with a thorough knowledge of pedagogical principles.

SCHOLARSHIPS.

Twenty scholarships were available for students of the School; ten of these were Bartol Scholarships in Drawing, derived from the B. H. Bartol Fund; ten scholarships were derived from the Isaac B. Thorn Fund, and were awarded to students in Mathematics and Naval Architecture.

PRIZES.

Valuable prizes were offered by the following gentlemen for meritorious work in various departments:

Mr. Samuel M. Vauclain, Vice-President, The Baldwin Locomotive Works.

Mr. J. B. McCall, President, Philadelphia Electric Co.

Mr. Wilfred Lewis, President, Tabor Manufacturing Co.

Mr. J. T. Wickersham, Secretary and Treasurer, The New York Shipbuilding Corporation.

Mr. Robert W. Lesley, Past-President, Portland Cement Association and Member of the Board of Managers of The Franklin Institute.

The Alumni Association continued its special prizes to the graduates having the best records and to graduates having a perfect attendance for the year.

HONORS.

Certificates for the satisfactory completion of a course in one of the Departments of Drawing or Mathematics were this year awarded to thirty-five students. There were no graduates in the Department of Mechanics and Naval Architecture, due in the former instance to the unusual demand of the government during the past two years for men with any knowledge whatever of engineering, and in the latter instance, to the extension of the course to include three years of instruction instead of two years as in the past. Appended are the names of the graduates, also the names of those students to whom are awarded the scholarships and prizes indicated above, and the names of those students granted certificates of Honorable Mention for regularity of attendance and proficiency in class work.

The success of the year that has just closed is due not only to the earnestness of the students and their continued application to the work assigned, but also to the close personal attention and sympathetic interest of the instructors.

Respectfully submitted,

LOUIS C. ROBINSON,
Director.

May 9, 1919.

LIST OF GRADUATES, 1918-'19.

CERTIFICATES

Certificates on the Satisfactory Completion of Full Courses are Awarded as Follows:

MECHANICAL DRAWING.

Samuel Alberti
Samuel H. Collins
Israel Cramer
Francis A. Harden
George Hiddeman, Jr.

James Linton
Edward E. Loesch
Paul L. Mentzer
John Mitchell
George Nairn

Oliver Patton
John Pollano
Frederick G. Spellier
Nelson S. Troughton
George F. Weber

ARCHITECTURAL DRAWING.

James Ballantyne
Roy Douglas
Charles F. Linder

MATHEMATICS.

B. Newton Barber
Walter Bird
James Cogan
J. K. Depuy
Charles W. Earley
Anthony R. Finnigan
Herbert Jacobs
Alfred J. Kautter
Joseph Kroulik
John McClelland
Julius A. Meister
James L. O'Neill
Herman Schaaf
Wilson D. Scott
William Lee Smith
Stanley K. Weber
Benjamin A. Wilson

BARTOL SCHOLARSHIPS.

DEPARTMENT OF DRAWING.

Mathew Alexy
  Mechanical
Walter Bruhns
  Architectural
Louis S. Carroll
  Mechanical
William E. Green
  Mechanical
Frederick P. Klein, Jr.
  Mechanical
Edwin C. Kunze
  Mechanical
Paul T. Morrison
  Mechanical
Joseph D. Quinn
  Mechanical
William J. Reed
  Free Hand
Thomas P. Walker
  Mechanical

THORN SCHOLARSHIPS.

DEPARTMENT OF MATHEMATICS.

Harry Brick
Frank Cohen
H. L. Evers
William J. Haessler
C. R. McCormick
Charles A. Schuler
Harold Turner
Charles Walker

DEPARTMENT OF NAVAL ARCHITECTURE.

J. S. Herbine
O. William Werner

PRIZES.

Paul L. Mentzer—S. M. Vauclain Prize—Mechanical Drawing.
James Ballantyne—Robert W. Lesley Prize—Architectural Drawing.
Herman Schaaf—J. B. McCall Prize—Mathematics.
Charles H. Buckler—Wilfred Lewis Prize—Mechanics.
Emil de Bruijn—New York Shipbuilding Corporation Prize—Naval Architecture.

ALUMNI PRIZES.

Herman Schaaf
  Mathematics
Charles H. Buckler
  Mechanics
Emil de Bruijn
  Naval Architecture
Paul L. Mentzer
  Mechanical Drawing
James Ballantyne
  Architectural Drawing

FREE MEMBERSHIP FOR ONE YEAR IN THE ASSOCIATION AWARDED TO GRADUATES.

Walter Bird
Samuel H. Collins
Anthony R. Finnigan
Francis A. Harden
Paul L. Mentzer
John Mitchell
George Nairn
Oliver Patton
Wilson D. Scott
Frederick G. Spellier

HONORABLE MENTION CERTIFICATES.

DEPARTMENT OF MATHEMATICS.

Walter Bird
Charles W. Earley
Joseph Kroulik
David McCartney
C. E. McClintock
Russell Morehouse
Harry Riley
Herman Schaaf
Wilson D. Scott
Benjamin A. Wilson

DEPARTMENT OF DRAWING.

Samuel Brethwaite
Israel Cramer
Catherine Day
Ida Sylvia Frost
William H. Gardner
Sarah J. Harvey
Joseph V. Hutelmyer
Herbert Jacobs
John V. Lindsay
Paul L. Mentzer
Herbert J. Morrill
Harry C. Meyer
George Nairn
George F. Palmer
Oliver Patton
Olive M. Stier

DEPARTMENT OF NAVAL ARCHITECTURE.

Harold B. Buckley
George F. Buckman
Emil de Bruijn
Ernest D. Hosking
Raymond H. MacAran
William J. Stanton
Joseph I. Tabakin
Charles M. Yater

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, May 14, 1919.)

NON-RESIDENT.

MR. EARL H. WELTZ, Chemist, E. I. du Pont de Nemours & Company, and for mail, Riverside Club, Pennsgrove, New Jersey.

CHANGES OF ADDRESS.

MAJOR JOHN H. BARR, care of Remington Typewriter Company, 374 Broadway, New York City, New York.

CAPTAIN LUCIUS P. BROWN, Love Field, care of Camp Surgeon, Dallas, Texas.

MR. JOHN CALDER, The Engineers' Club, 32 West 40th Street, New York City, New York.

MR. E. M. FITZ, Room 611, New First National Bank Building, Columbus, Ohio.

MR. H. GOODWIN, JR., Power and Mining Department, General Electric Company, Schenectady, New York.

MR. RICHARD P. HARVEY, 71 First Street, San Francisco, California.

MR. EDWARD HEITMANN, Fairmount Hotel, 2595 Boulevard, Jersey City, New Jersey.

MR. WILLIAM HOPPIN, 1521 Mt. Vernon Street, Philadelphia, Pennsylvania.

MR. CLINTON N. LAIRD, Room 918, 156 Fifth Avenue, New York City, New York.

MR. ARTHUR W. LOWE, 1224 Herbert Street, Frankford, Philadelphia, Pennsylvania.

MR. THOMAS S. MARTIN, Hermit Lane, Roxborough, Philadelphia, Pennsylvania.

MR. H. H. MAXFIELD, Pennsylvania Railroad Company, Altoona, Pennsylvania.

MR. WILLIAM S. MURRAY, 165 Broadway, New York City, New York.

MR. H. B. OATLEY, 145 Wilson Avenue, Flushing, New York.

MR. L. T. SHERWOOD, P. O. Box 196, Carney's Point, New Jersey.

MR. R. JOHN TITZEL, 601 Swede Street, Norristown, Pennsylvania.

MR. JOHN A. VOGLESON, 8009 Crefeldt Street, Philadelphia, Pennsylvania.

LIEUTENANT COLONEL FRED. H. WAGNER, The Lombardy Apartments, 39th Street and Stony Run Lane, Baltimore, Maryland.

MR. J. F. WARWICK, 61 Crew Street, Atlanta, Georgia.

MR. G. A. WELLS, 1067 Madison Avenue, New York City, New York.

MAJOR R. A. WIDDICOMBE, 1025 Hollywood Avenue, Chicago, Illinois.

MR. GEORGE M. YORKE, 70 Irving Place, New York City, New York.

NECROLOGY.

Thomas Skelton Harrison was born in Philadelphia on September 19, 1837, and died on May 3, 1919. Mr. Harrison was educated in the private school of John W. Faires, and later entered the University of Pennsylvania. Finding commercial life more attractive than the learned professions, he discontinued his studies at the University and obtained a position at the Pennsylvania Sugar Refinery. In July, 1861, he became Pay Master in the United States Navy and served until August, 1864.

When Mr. Harrison left the Navy he became a partner in the firm of Harrison Brothers and Company, with which he was connected for nearly forty years. For many years he served as President of the Manufacturing Chemists' Association of the United States. He also took an active interest in the Centennial celebration in Philadelphia in 1876, serving on numerous committees which were organized at that time to further the objects of the exhibition.

Mr. Harrison was prominent in public affairs in his native city. In 1871 he was appointed Consul-General of the United States at Cairo, Egypt. Mr. Harrison derived most pleasure, however, from his activities in the fields of commerce, to which he had devoted the greater part of his life. He was connected with numerous technical, military and social organizations, and became a member of The Franklin Institute on March 5, 1901.

James Hamilton Windrim was born in Philadelphia, July 4, 1840, and died at Merion, Pa., on April 26, 1919. His educational training was obtained at Girard College, to which he was admitted at an early age. On leaving the college in 1856 he began the study of architecture under John Notman, a noted architect. When twenty years of age he was engaged to take full charge of the construction and erection of one of the largest hospital buildings in Philadelphia. Upon the completion of this work he was appointed to the Pennsylvania Railroad Company's corps of architects and was placed in charge of the planning and construction of the company's Union Depot at Pittsburgh. In later years he superintended the construction of several of the larger mansions in the suburbs of Philadelphia.

Having achieved a reputation, he found his services in constant demand for important and costly public buildings, as well as private residences. Nearly all of the large cities of the East have among their chief ornaments some example of his ability as an architect. The Masonic Temple in Philadelphia is considered by many his masterpiece.

In 1871 he was appointed architect for the Girard Estate by the Board of City Trusts of Philadelphia, and in this capacity designed and superintended improvements of the real estate controlled by the Board throughout the city, and erected a number of buildings in the grounds of Girard College. In 1889 he was appointed Supervising Architect of the United States, and held this position until April, 1891, when he resigned to accept the office of Director of the Department of Public Works of the City of Philadelphia. After four years he retired from public life and resumed the practice of his profession.

Mr. Windrim became a member of the Institute on January 22, 1867.

Mr. W. H. Albertson, 334 North Preston Street, Philadelphia, Pennsylvania.

Dr. Annabella E. Richards, 2503 Maryland Avenue, Baltimore, Maryland.

LIBRARY NOTES.

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Schaeffer and Budenberg Manufacturing Company, Catalogue No. 300. Brooklyn, New York, 1918. (From the Company.)

Snyder, J. E. & Son, Catalogue of Upright Drills. Worcester, Massachusetts, 1919. (From the Company.)

Strauss Bascule Bridge Company, Seventy-page Catalogue. Chicago, Illinois, 1919. (From the Company.)

Taylor Welder Company, Booklet, entitled Electric Welding. Warren, Ohio, no date. (From the Company.)

Truscon Steel Company, Catalogue on Hy-Rib and Metal Lath. Youngstown, Ohio, 1919. (From the Company.)

University of Tennessee, Manual for Engineers. Knoxville, Tennessee, 1904. (From the University.)

United Engineering and Foundry Company, Bulletin, entitled United Precision Cold Strip Mills. Pittsburgh, Pennsylvania, 1919. (From the Company.)

United States Shipping Board, Report of the Director of Marine and Dock Industrial Relations Division. Washington, District of Columbia, 1919. (From the Board.)

Waterbury Company, General Catalogue, New York City, New York, 1918. (From the Company.)

Wellman Seaver Morgan Company, Bulletin No. 19. Akron, Ohio, 1919. (From the Company.)

Winfield Electric Welding Machine Company, Catalogues: Electric Welding of High Speed Tool Steel; Directions for Installing and Operating Winfield L & M Type Spot Welding Machines. Warren, Ohio, no date. (From the Company.)

Whiting Foundry Equipment Company, Catalogue No. 135. Harvey, Illinois, no date. (From the Company.)

Whitman and Barnes Manufacturing Company, Catalogue No. 91. Akron, Ohio, 1919. (From the Company.)

Wolf Company, Catalogue No. 18. Chambersburg, Pennsylvania, no date. (From the Company.)

BOOK NOTICES.

AN INTRODUCTION TO THE PHYSICS AND CHEMISTRY OF COLLOIDS. By Emil Hatschek. Third edition, 110 pages, contents and index, illustrations, 12mo, Philadelphia, P. Blakiston's Son & Company, 1919. Price, $1.50 net.

The second edition of this work was reviewed in this JOURNAL three years ago. The present issue differs by the addition of some pages due to the incorporation of new matter. Some minor errors have been corrected. Inasmuch as since the appearance of the second edition several large text-books have been issued in English and Ostwald's "Grundriss der Kolloidchemie" is now available in English form, the author has not thought it necessary to enlarge materially the scope of the book. It is a very readable and informing summary of the important facts in the field to which it is devoted.

HENRY LEFFMANN.

PUBLICATIONS RECEIVED.

U. S. Bureau of Mines: Bulletin 169. Illinois Mining Statutes Annotated, by J. W. Thompson. Including all Illinois Mining Laws. 594 pages, 8vo. Monthly Statement of Coal-Mine Fatalities in the United States. January, 1919. List of Permissible Explosives, Lamps, and Motors Tested Prior to February 28, 1919, compiled by Albert H. Fay. 25 pages, 8vo. Technical paper 178. Notes on Lignite, Its Characteristics and Utilization, by S. M. Darling. 19 pages, 8vo. Technical paper 209. Traps for Saving Gas at Oil Wells, by W. R. Hamilton. 34 pages, illustrations, plates, 8vo. Technical paper 213. Quarry Accidents in the United States During the Calendar Year 1917, compiled by Albert H. Fay. 62 pages, 8vo. Washington, Government Printing Office, 1919.

North Carolina Geological and Economic Survey: Biennial Report of the State Geologist, 1917–1918. 110 pages, illustrations, 8vo. Raleigh, State printers, 1919.

Public Ownership: The Solution of Chicago's Transportation Problem. Suggested Constructive Program, adopted by the Chicago Municipal Ownership League (affiliated with the Public Ownership League of America) and submitted to the City Council of Chicago. 16 pages, 8vo. Chicago, Municipal Ownership League, 1919.

Railways and Waterways An Address by Walker D. Hines, Director General of Railroads. Delivered before the fourteenth convention of the National Rivers and Harbors Congress, Washington, D. C., February 7, 1919. 8 pages, 8vo.

A Gratifying Change of Front: An Address by Hon. J. Hamilton Lewis, U. S. Senator from Illinois. Delivered before the fourteenth convention of the Rivers and Harbors Congress, Washington, D. C., February 7, 1919. 7 pages, 8vo.

Commercial Production of Helium for the Inflation of Dirigibles. ANON. (*Revue Generale des Sciences,* vol. xxx, No. 7, p. 195, April 15, 1919.)—One of the most remarkable technical achievements of war-time activities is the preparation of helium in quantities sufficient for the inflation of dirigibles. Helium is a light gas, comparable in this respect with hydrogen, and possessing a lifting force of 92 per cent. of the latter. It has the very great advantage over hydrogen in being neither inflammable nor explosive, properties which make it possible to place the operating motors within the gas bag; moreover, the diffusion losses of helium are less than those of hydrogen.

Helium is abundant in the sun but is rare on the surface of the earth, where it is only found with the gases given off by heating certain radio-active minerals or in certain natural gases. Before the war, only very small amounts had been collected, and at a very high cost. On the recommendation of Sir R. Threlfall, who had made an extensive study of the sources of helium and the costs of its preparation and transportation, the British admiralty undertook the further development of the project. It was found that certain natural gases of Canada contain about ⅓ per cent. of helium, and a research laboratory for the purpose was established at the University of Toronto. When the United States entered the war, the United States Bureau of Mines also took up the project with the object of exploiting the sources of helium of the country. Due to the vigorous prosecution of this work, the industrial production of helium was established in 1918. When hostilities ceased, 4100 cubic metres of almost pure helium were at hand, compressed and ready for transport, and plants were already under construction for the manufacture of 1400 cubic metres of helium per day at a price not exceeding 18 francs per cubic metre.

CURRENT TOPICS.

Improving the Quality of Gray Iron by the Electric Furnace. G. K. Elliott. (*Proceedings of the American Electrochemical Society*, April 3–5, 1919.)—All ordinary grades of gray iron—those with medium and high percentages of phosphorus—cannot be melted more easily or more economically than in the cupola. For melting efficiency, this furnace takes precedence over its two closest rivals, the reverberatory or air-furnace, and the regenerative open-hearth furnace. For simplicity of construction, low cost of installation and up-keep, ease of operation, and economy of melting, it has no competitors; and there is no probability that, for the great run of ordinary gray-iron castings, it will ever be displaced, although its improvement is conceivable. From the standpoint of process alone, the cupola is almost impeccable; but from the high ground of product, it shows serious faults. The cupola is not a refining furnace, and sometimes its hottest iron is not hot enough for the best casting results. Supertenacious and solid iron demands the attainment of hotter iron. This requires either the elimination of the cupola or the introduction of a duplex process.

For a superheating furnace, supplemental to the cupola, there are several eligible types. Among these are the reverberatory furnace, the regenerative furnace, and the electric furnace. For really extraordinary castings the author believes the arc electric furnace presents the most promising possibilities. The foundry with which the author has been connected has made a specialty of high-pressure steam valve castings with extreme solidity exacted. Experience in the manufacture of this product has indicated that the basic-bottom arc electric furnace is the best auxiliary for the cupola in a duplex process for the production of truly high-grade gray-iron castings. Carbon regulation, total as well as combined and graphitic, is possible to a most useful extent in the electric furnace, and the basic electric furnace removes most of the sulphur while the metal is being superheated. Another advantage accruing from the electric furnace is the possibility of making furnace additions of manganese and other elements for particular purposes without having to expect more or less appreciable losses; the manganese losses are *nil*. The electric furnace duplex process for gray iron is not recommended as a commercial practicability for ordinary iron castings under ordinary circumstances, but rather as a convenient and extremely efficacious substitute for the cupola process for extraordinary castings or for extraordinary circumstances.

New Outline Map of the United States on the Lambert Projection. ANON. (*Circular, U. S. Coast and Geodetic Survey,* May 20, 1919.)—Many methods of projection have been designed to solve the difficult problem of representing a spherical surface on a plane. As different projections have unquestionable merits as well as equally serious defects, any region to be mapped should be made the subject of special study and that system of projection adopted which will give the best results for the area under consideration. The Mercator Projection, almost universally used for nautical charts, is responsible for many false impressions of the relative size of countries differing in latitude. The polyconic projection, widely used and well adapted for both topographic and hydrographic surveys, when used for the whole of the United States in one map, has the serious defect of unduly exaggerating the areas on its eastern and western limits.

The U. S. Coast and Geodetic Survey, Department of Commerce, reports the completion of the new outline map of the United States on the Lambert Conformal Conic Projection, scale 1-5,000,000, dimensions, 25 x 39 inches, price, 25 cents. This map is intended merely as a base to which may be added any kind of special information desired. The shoreline is compiled from the most recent Coast and Geodetic Survey charts. State names and boundaries, principal rivers, capitals and largest cities in the different states, are the only information otherwise embodied.

The map is of special interest from the fact that it is based on the same system of projection as that which was employed by the armies of the allied forces in the military operations in France. To meet those requirements and at the request of the army, special publications were prepared by the Coast and Geodetic Survey. The value of the new outline map on the Lambert projection can best be realized when it is stated that throughout the larger and most important part of the United States, that is, between latitudes 30½° and 49° the maximum scale error is only one-half of one per cent. This amount of scale error of one-half of one per cent. is frequently less than the distortion due to the method of printing and to changes from the humidity of the air. Only in southernmost Florida and Texas does this projection attain its maximum error of 2⅓ per cent.

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